J.A. Barceló

Form and Function
Advantages of 3D Modeling and Geometric Reasoning

ARCHAEOLOGY IS A QUINTESSENTIALLY VISUAL DISCIPLINE

?

EXPLANATIONS

DATA

We want to see what cannot be seen

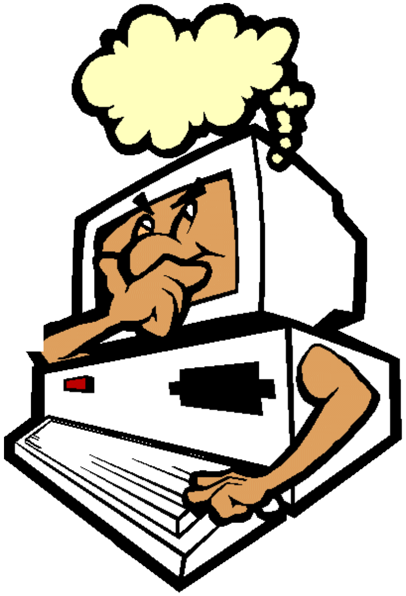

For Archaeologists
Only

Problem Solving in Archaeology

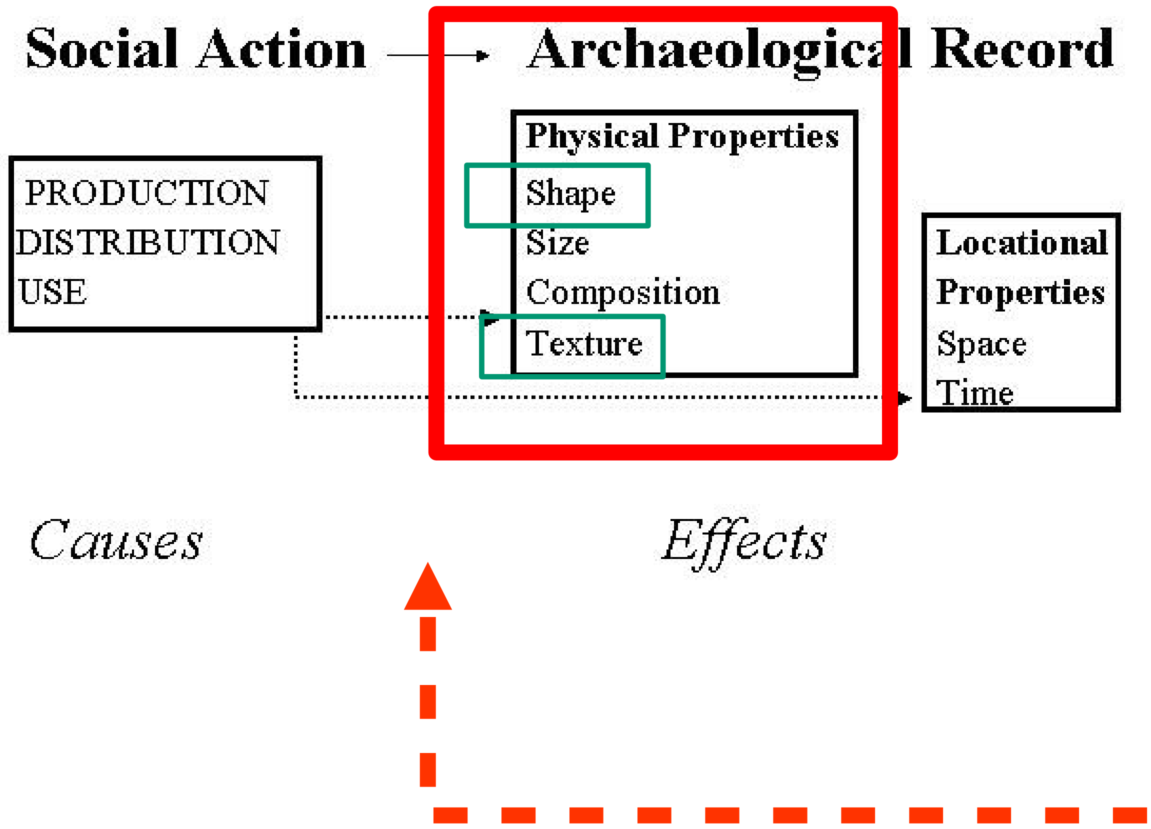
Social Action ⟶ **Archaeological Record**

PRODUCTION DISTRIBUTION USE	**Physical Properties** Shape Size Composition Texture	**Locational Properties** Space Time

Causes *Effects*



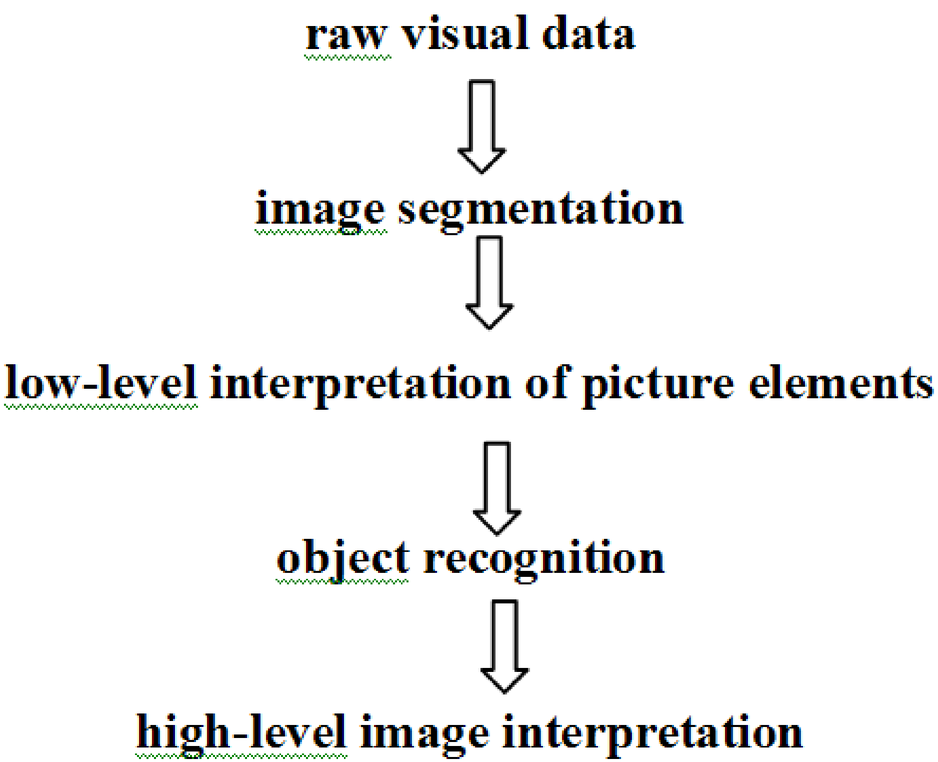
Problem Solving in Archaeology



Visual Information

- When we see something, we are not seeing an object, but our senses capture sensorial information (luminance contrasts), which should then be transformed into an intermediate-level representation of what gives the perceived entity its individuality.

VISUAL INFORMATION



Low-level information is typically about the spatial relationships among primitive, two-dimensional visual features such as observed shape, texture, and composition variability patterns.

Intermediate information describes the properties arising from forms of organization of the low-level primitives, and may include descriptions of the three-dimensional spatial relationship (location) among visual properties.

The overall explanatory process is thus broken down into the extraction of a number of different observable physical properties (low-level analysis), followed by a final decision based on these properties (high-level analysis), what implies breaking down the perception of meaningful visual marks into different explanatory stages

Visual Information

- Formally speaking, a *surface is a boundary of separation between two phases*.
- In its turn, a *phase is a homogenous mass of substance*, *solid*, *liquid or gas*, *possessing* a well-defined boundary.
- When we have two phases in mutual contact, we have an *interface*.

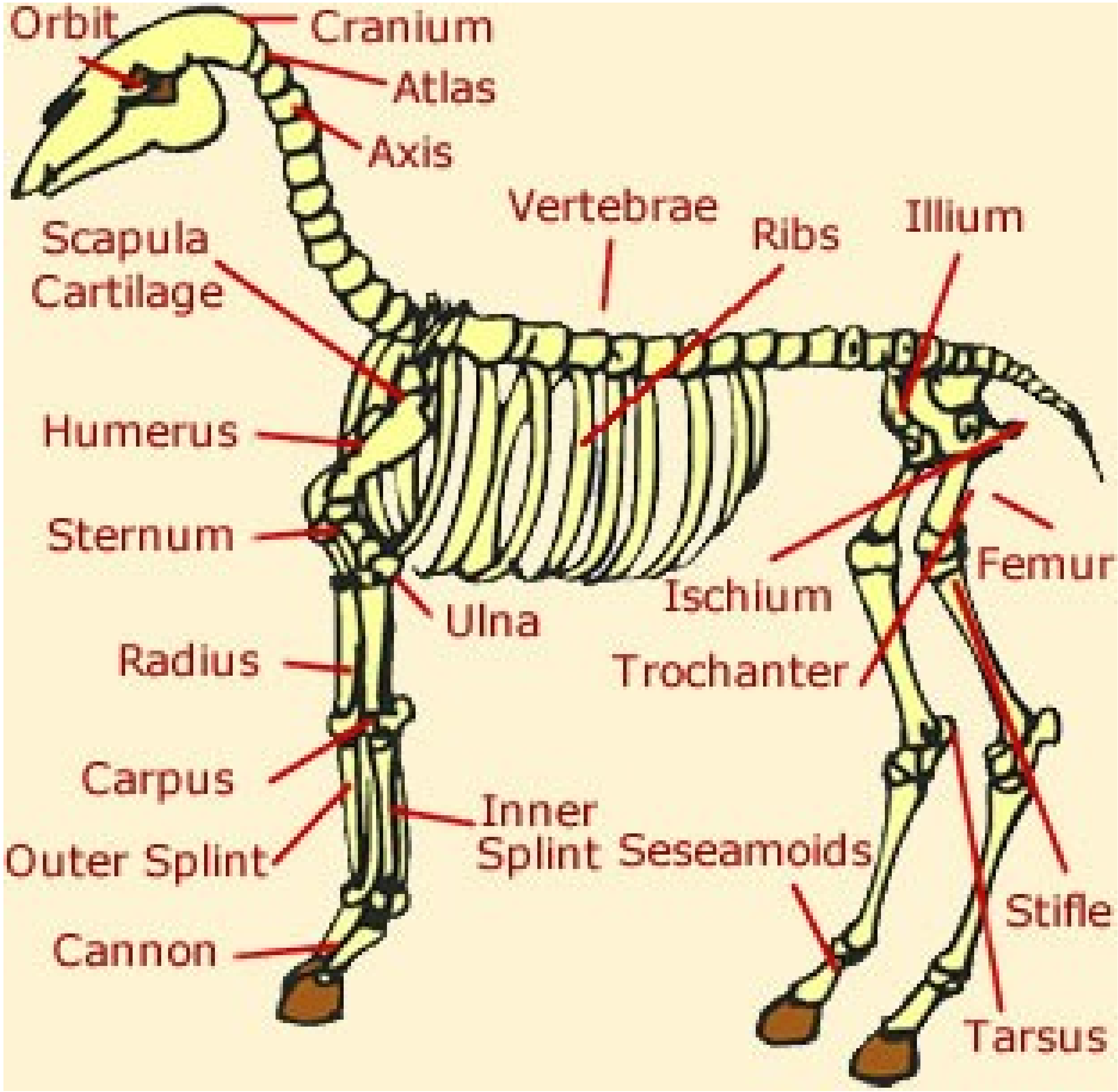
Visual Information

- The surface of solids plays a significant role to discover the way they have been produced and the way they have been used.
- Surfaces have two main properties: *shape and texture*.

What is Shape?

Scientists have traditionally assumed that there is a roughly fixed set or vocabulary of "supposed" descriptive visual regularities shared by a single population of objects, which are also distinctive enough.

Scientists believe that what they see is a "seed", a "bone", a "bowl", "a knife", the "wall of a house", a "prince burial", etc., and they can distinguish between different kinds of "bowls", different kinds of "prince burials", and so on.


Orbit
Cranium
Atlas
Axis
Vertebrae
Ribs
Illium
Scapula
Cartilage
Humerus
Sternum
Ulna
Ischium
Femur
Radius
Trochanter
Carpus
Inner
Splint
Seseamoids
Outer Splint
Stifle
Cannon
Tarsus

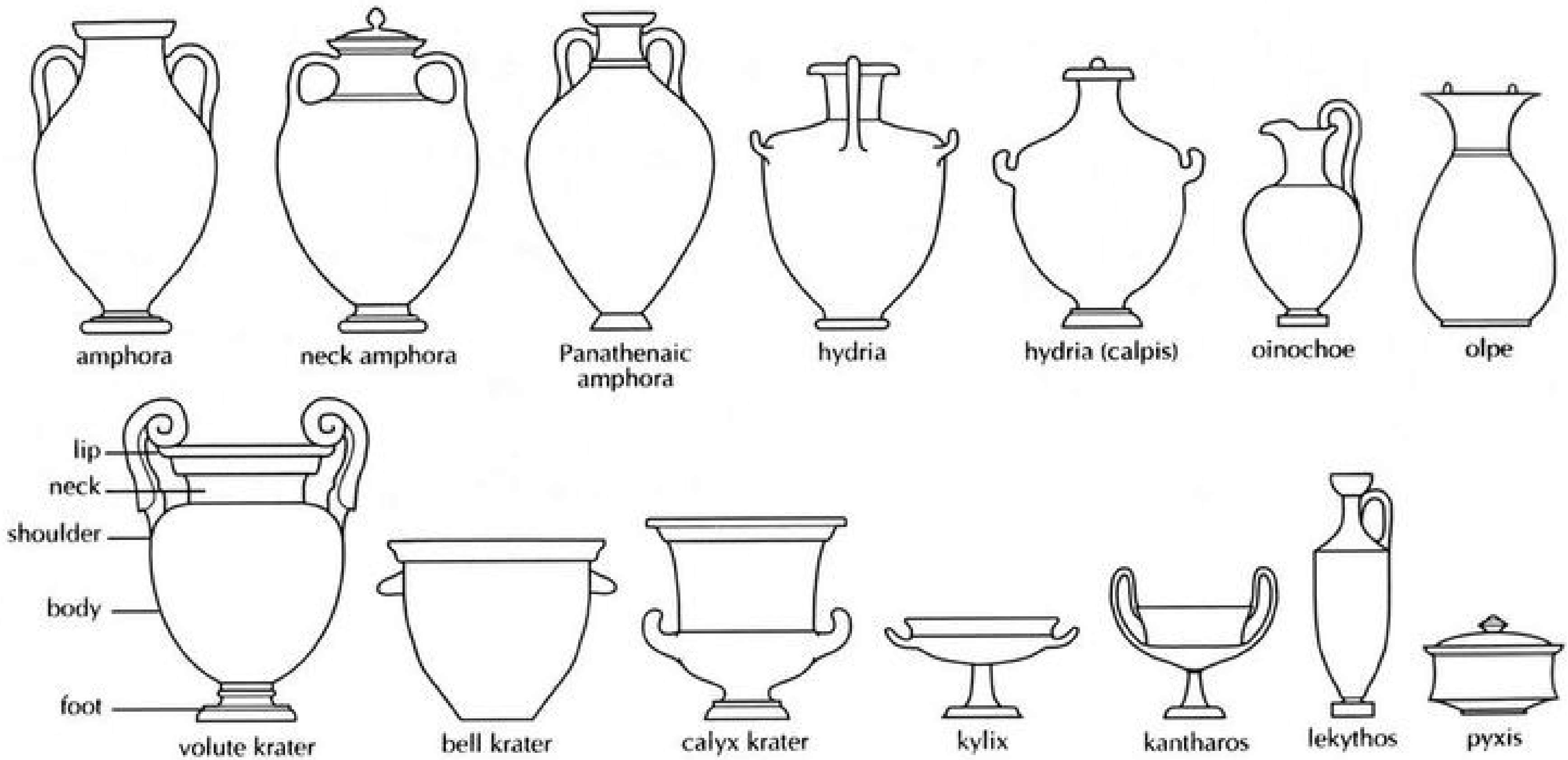

amphora
neck amphora
Panathenaic amphora
hydria
hydria (calpis)
oinochoe
olpe
lip
neck
shoulder
body
foot
volute krater
bell krater
calyx krater
kylix
kantharos
lekythos
pyxis

TABLE PREHENSION

- ❑ **préhension appliquée**
- ❑ **préhension tirée**
- ❑ **ensellement médian**

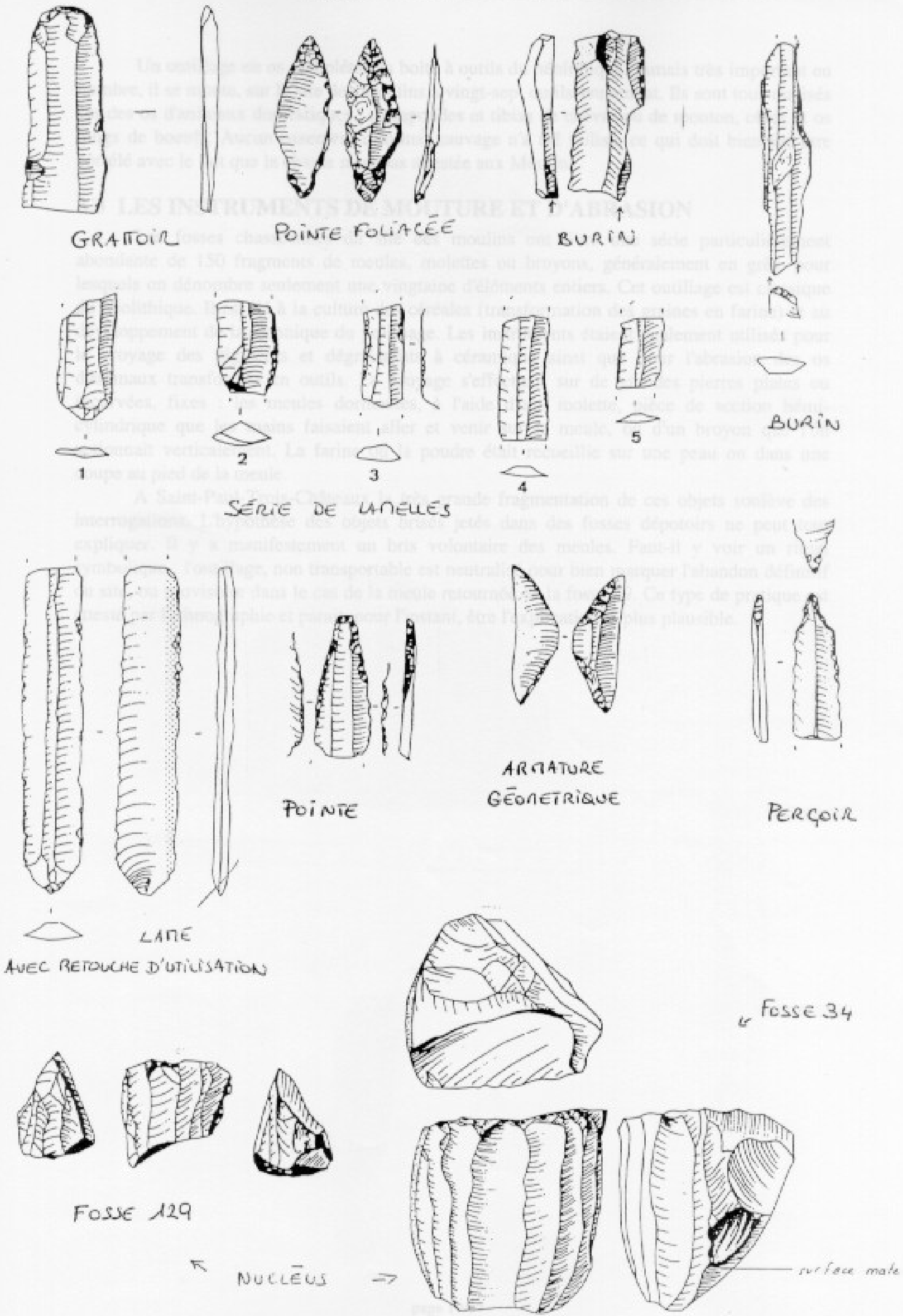
	Type	Localisation	Associé à	Orientation
Enum	- anse en boudin	- sous la lèvre	- élément plastique	- verticale
	- anse en boudin à arc cintré	- sur la lèvre	- élément préhension	- oblique
	- anse en boudin à arc coudé	- à prise directe sur la lèvre	- élément en relief	- horizontale
	- anse en boudin à angle droit	- sur le bord	- décor en relief	- indéterminable
	- anse en ruban	- sur le col	- décor en creux	
	- anse en ruban à arc cintré	- sur la panse	- indéterminable	
	- anse en ruban à arc coudé	- en haut de la panse		
	- anse en ruban à angle droit	- au milieu de la panse		
	- anse en demi-bobine	- en bas de la panse		
	- anse « ad ascia »	- à cheval lèvre/bord		
	- mamelon	- à cheval lèvre/col		
	- mamelon allongé	- à cheval lèvre/panse		
	- mamelon prismatique	- à cheval bord/panse		
	- préhension en demi-bobine	- à cheval col/panse		
	- préhension en demi-cylindre	- au-dessus de la carène		
	- préhension en H	- sur la carène		
	- préhension en X	- au-dessous de la carène		
	- prise plate	- rattachée au-dessus de la carène		
	- prise plate à développement arrondi	- rattachée au-dessous de la carène		
	- prise plate à développement rectangulaire	- indéterminable		
	- indéterminable			
	- préhension tubulaire à développement arrondi			
	- préhension tubulaire à développement rectangulaire			

Perforation affectant la préhension

- **nombre de perforation** [ ]
- ❑ **sous-cutanée**

	Orientation perfo/récipient	Orientation perfo/préhension
Enum	- verticale	- transversale
	- oblique	- longitudinale
	- horizontale	- indéterminable
	- indéterminable	

INDUSTRIE LITHIQUE DES MOULINS



Tipologie Analytique

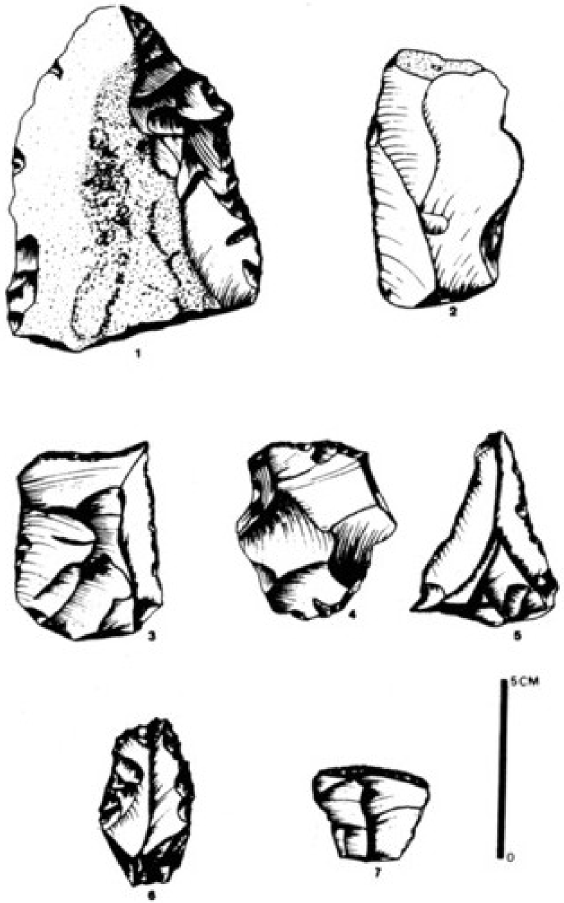


Figure III

1 : retouche simple, profonde, latérale : racloir latéral.

2 : retouche simple, marginale, latérale : racloir latéral.

3 : même type de retouche mais latérale et transversale : racloir latéro-transversal.

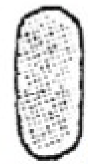
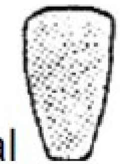
4 : retouche simple, profonde, transversale : racloir transversal.

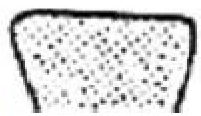
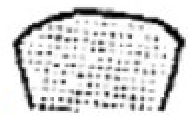
7 : même type que 4, mais en retouche marginale : racloir transversal.

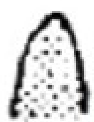
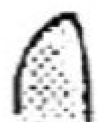
6 : retouche simple, profonde, latérale. Le bord dextre est denticulé. Un front à peine ébauché ne peut être interprété comme grattoir. Il s'agit d'un racloir denticulé.

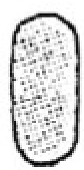
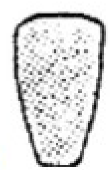
5 : le bord dextre est un racloir latéral partiel. Le bord senestre présente une retouche abrupte, marginale, qui dans sa partie proximale rencontre une cassure concave aménagée : il s'agit d'un bec.

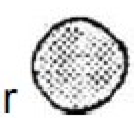
- Para su **descripción** tenemos en cuenta los siguientes parámetros:
    - **Forma de la pieza** (en visión frontal):

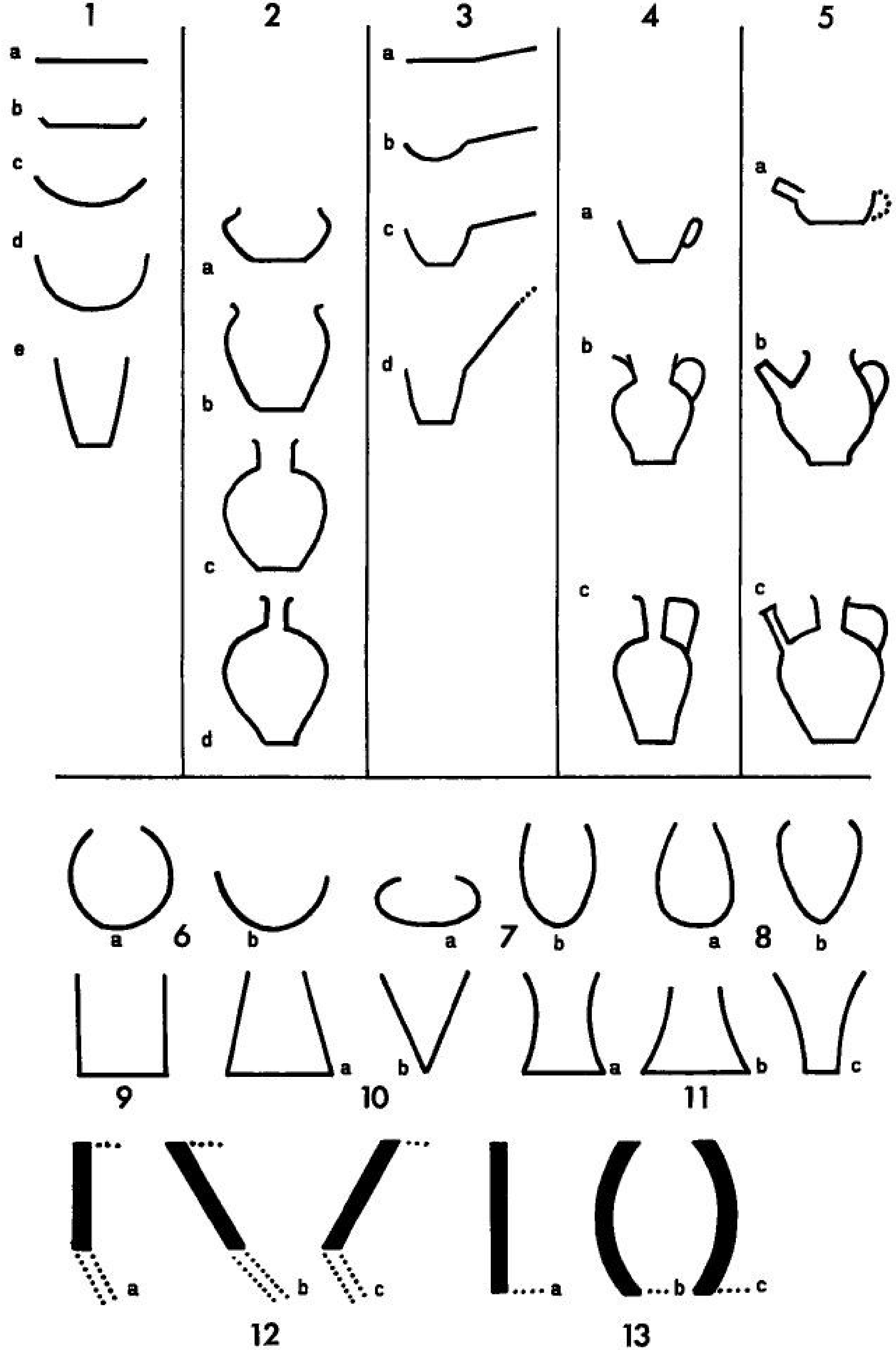
      Triangular  ; rectangular ; trapezoidal 
    - **Filo** (en visión frontal):

      Rectilíneo  ; curvo 
    - **Perfil del filo**:

      Simétrico  ; asimétrico 
    - **Base** (en visión frontal):

      Redondeada  ; recta 
    - **Sección**:

Rectangular  ; en media luna ; oval ; circular 


1
2
3
4
5
a
b
c
d
e
a
b
c
d
a
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c
d
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b
c
a
b
c
a
6
b
a
7
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10
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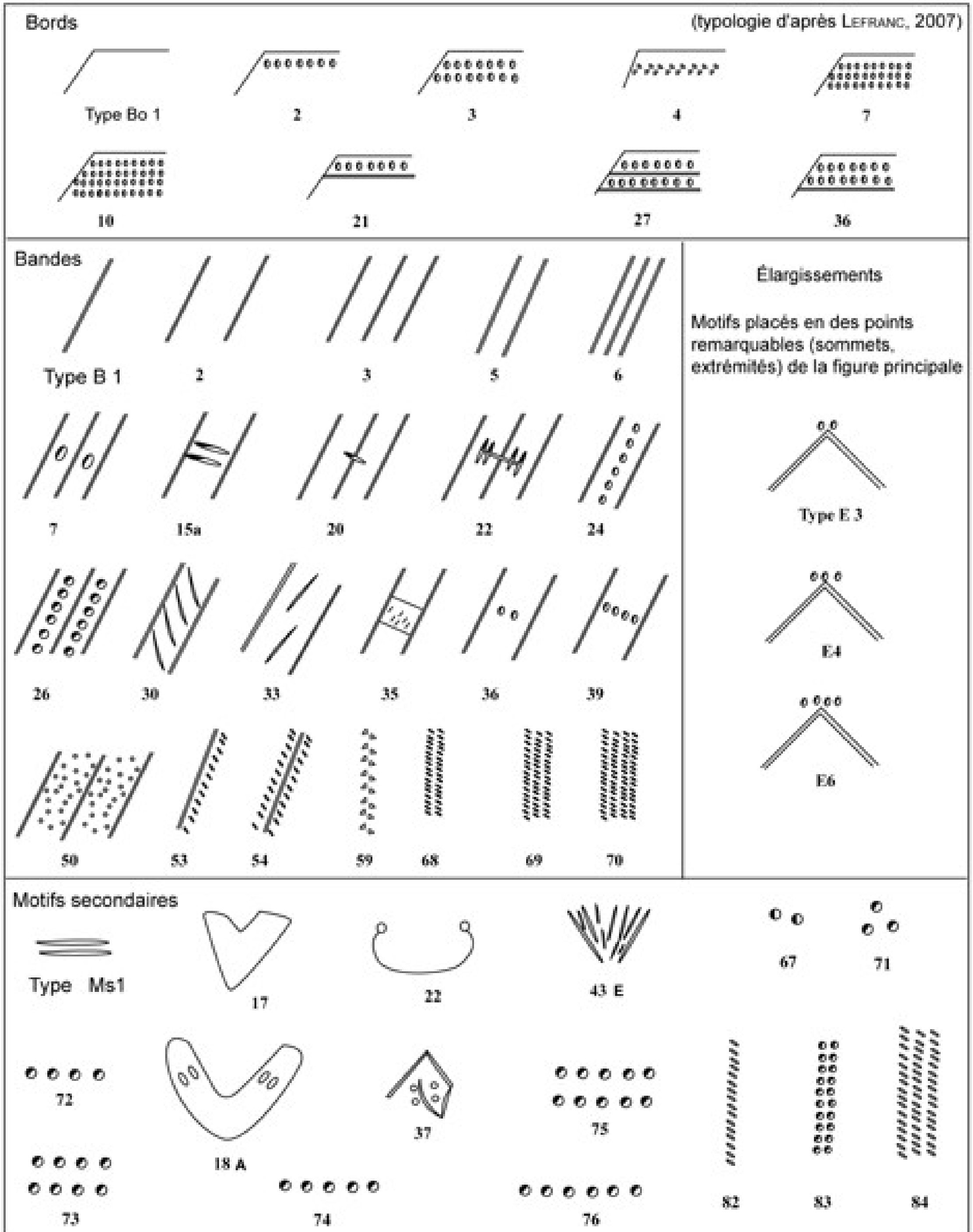
11
c
a
b
c
12
a
b
c
13



Bords
(typologie d'après Lefranc, 2007)
Type Bo 1
2
3
4
7
10
21
27
36
Bandes
Type B 1
2
3
5
6
7
15a
20
22
24
26
30
33
35
36
39
50
53
54
59
68
69
70
Élargissements
Motifs placés en des points remarquables (sommets, extrémités) de la figure principale
Type E 3
E4
E6
Motifs secondaires
Type Ms1
17
22
43 E
67
71
72
18 A
37
75
73
74
76
82
83
84

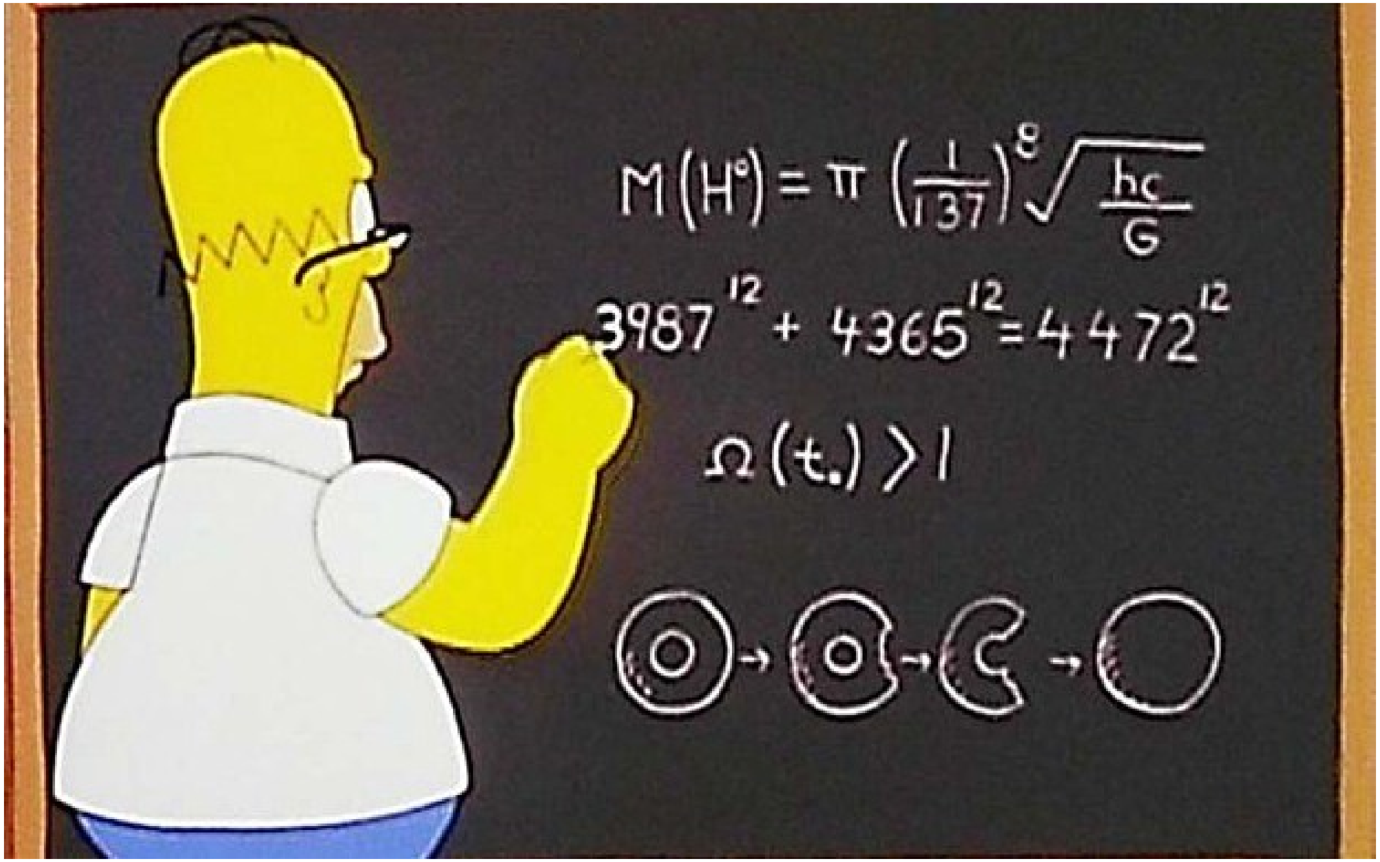
This way of identification-based explanation seems then a tricky way of solving any archaeological research problem.

It pretends to explain what has been “seen”, not in terms of their visual characteristics, but in terms of subjective recognition.

Nevertheless, what we“see” in the real world are not stones, walls, pit holes, mounds, buildings, pottery sherds, plants, animal carcasses, or anything like but a hierarchized organization of visual marks and higher level cues to explanatory categories.

What is Shape?

Shape is a quantitative property



Quantitative Properties

QUANTITY: any property that can be expressed in terms of an intensity.

QUALITY: any property that can only be expressed in terms of presence/absence

Quantitative Properties

Verbal language is not appropriated for describing intensities:

“a lot of”,

“small”

“large”

“tall”

Quantitative Properties

There is not a "mathematical" reality, nor "mathematical concepts".

There are real things, empirical properties that SHOULD be described in terms of their intensities…….

Measuring

Measuring is the operation of assigning numbers that represent the degree or intensity a property is present in some entity

Measuring Instruments

It is a device, a procedure or a set of logical formal operations that compare a reference ordination to the actual state of the property at the measured entity

Measuring

<u>Fast everything observable in reality is a quantity,</u>

Happiness, Love,……

they are always refered as if they would exist in“quantities”

I am “very” happy…

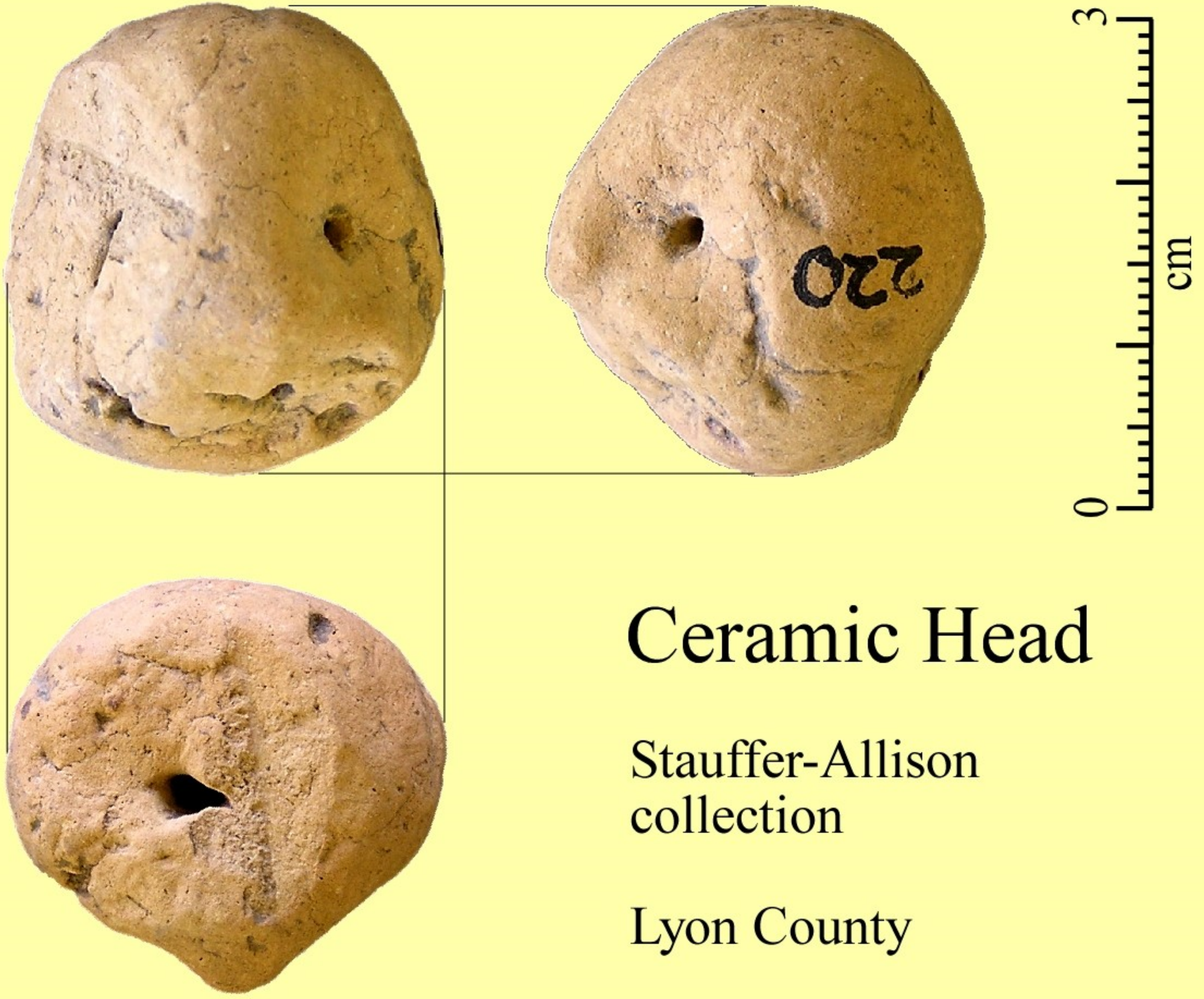
I love you less and less….)

<u>But we do not know how to measure those properties</u>

Measuring Shape

We do not have the habitude of measuring shape in archaeology, but it is far easier than measuring happiness or love…..

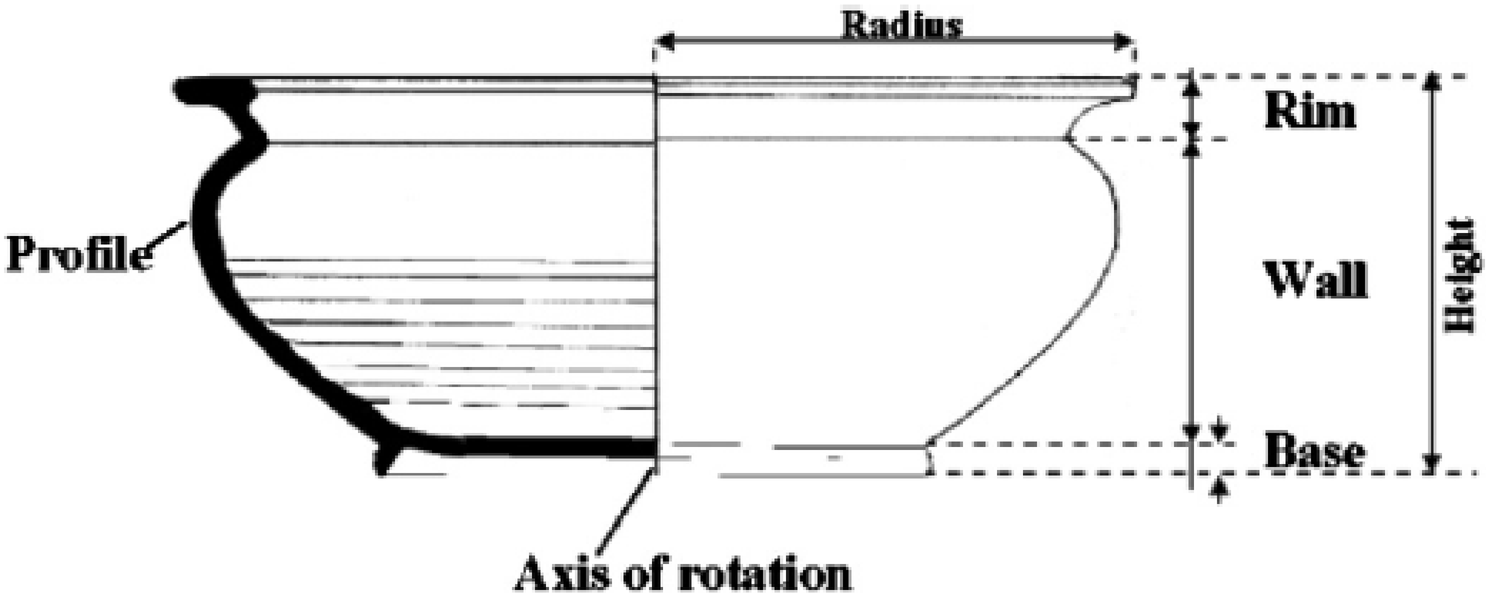
Shape is not Size



Ceramic Head

Stauffer-Allison collection

Lyon County



Radius
Rim
Profile
Wall
Height
Base
Axis of rotation

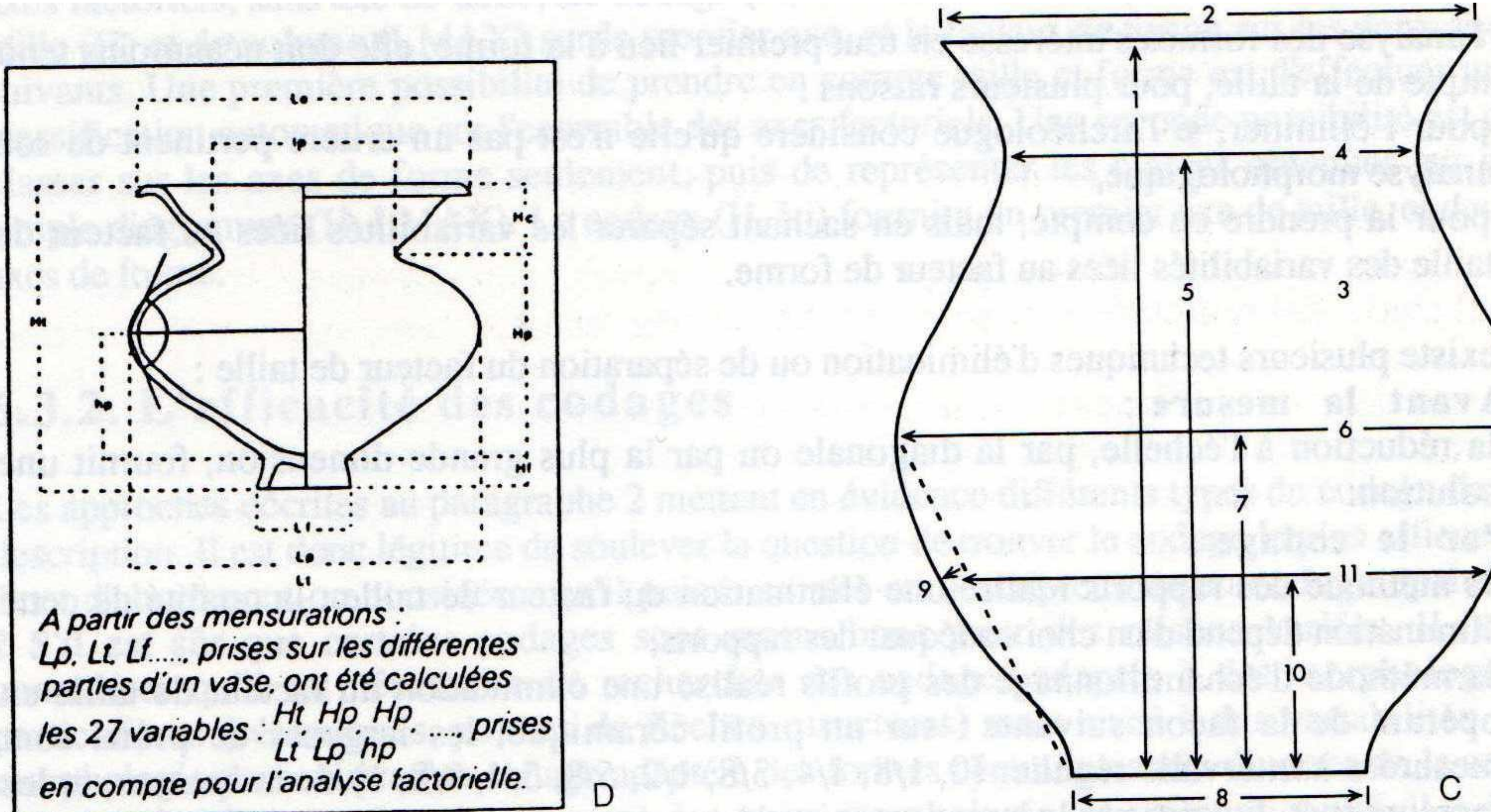


Fig. 6.3 : Différents exemples de mensurations

d) : Céramiques (d'après Mohen, 1980) c) : Céramiques (d'après Whallon, 1982).

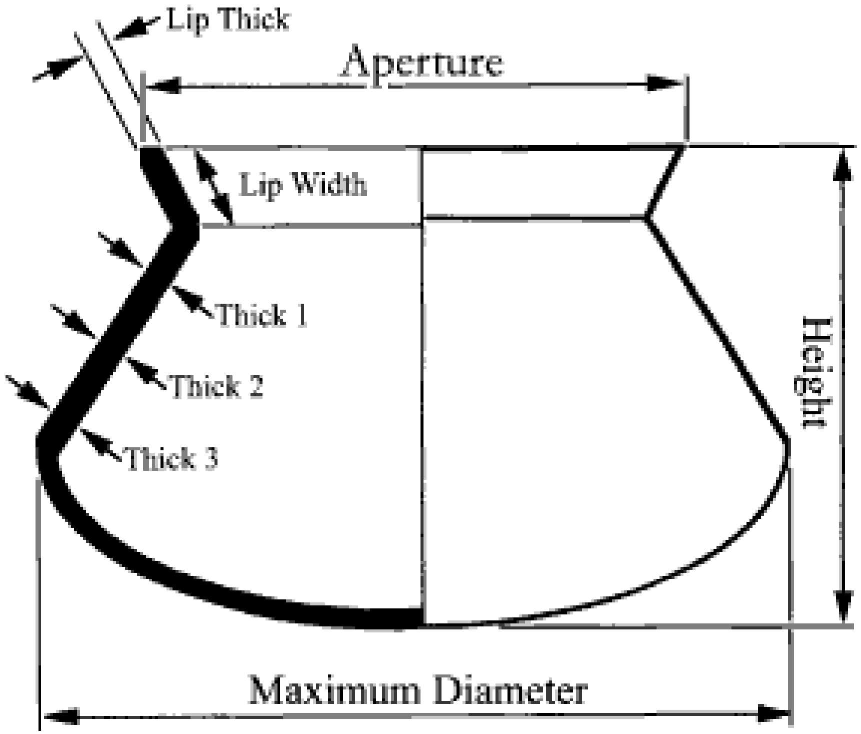


Figure 1. Measurements taken on Andra Pradesh vessels (*ralla catti*).

enable us to calculate indexes of regularity in the

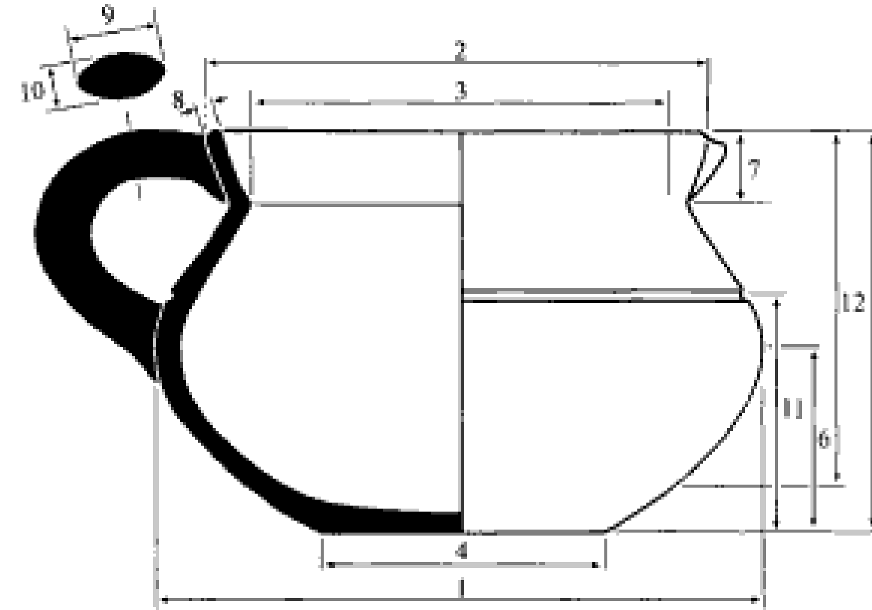


Figure 2. Measurements taken on Spanish vessels. (1) Maximum diameter, (2) aperture, (3) neck diameter, (4) base diameter, (5) total height, (6) maximum diameter height, (7) lip height, (8) lip thickness, (9) handle width, (10) handle thickness, (11) height of the decor (distance between the bottom and an incised groove), and (12) height of the zone which has not been turned.

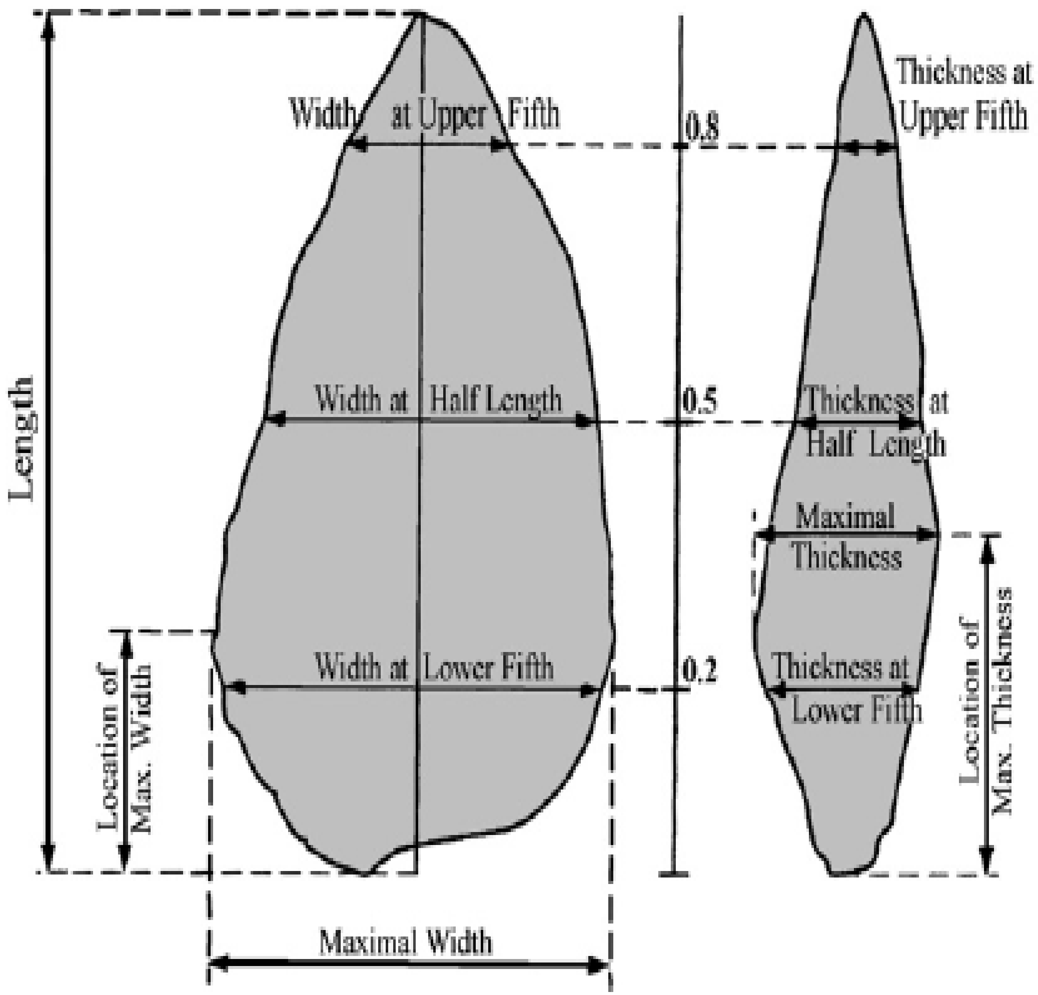


Fig. 1. Conventional positioning and basic measurement extraction (from Roe, 1964 and after Sharon, 2007).

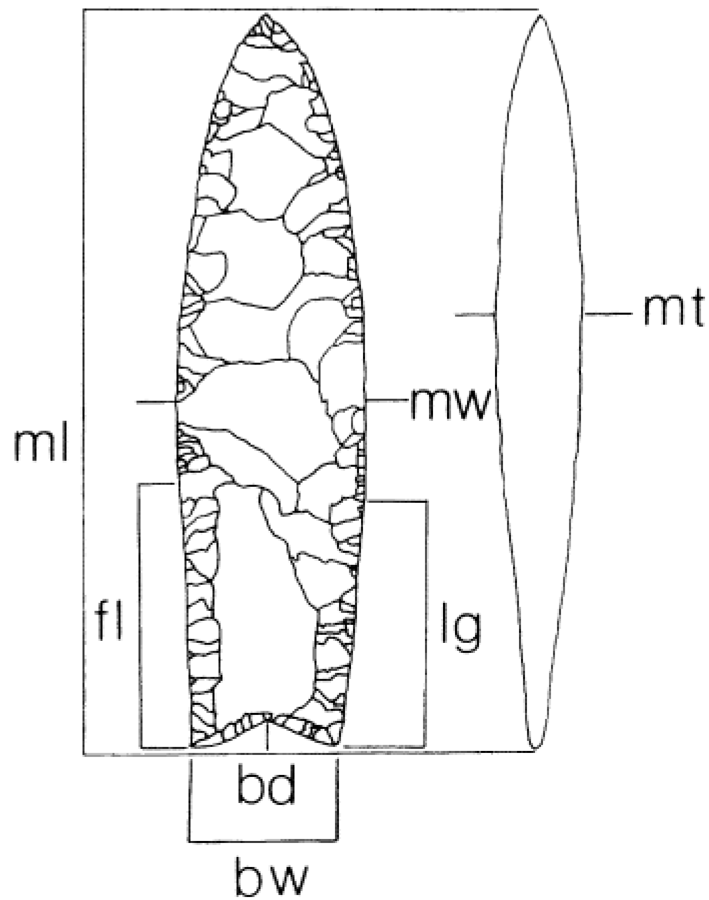
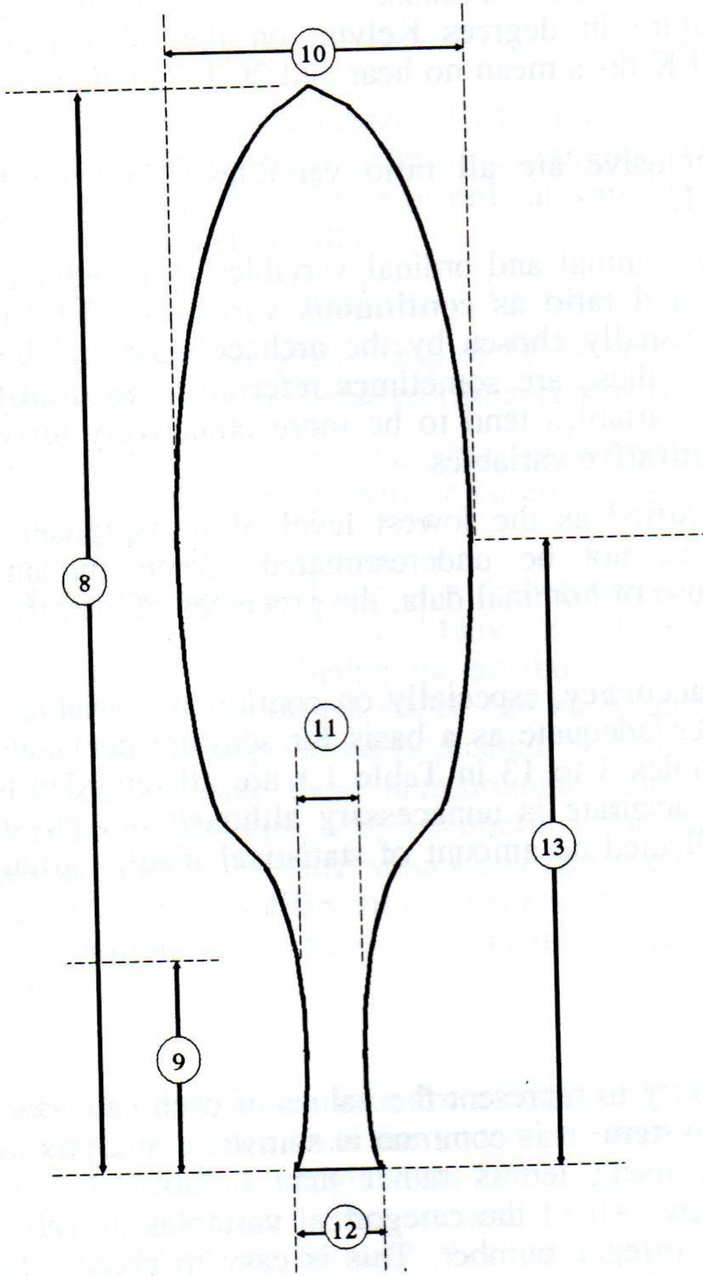


Figure 1. Standard fluted-point morphometric landmarks: (ml) maximum length, (mw) maximum width, (lg) extent of lateral grinding, (bw) basal width, (bd) basal depth, (fl) fluting-scar length, and (mt) maximum thickness.

Variable number



8. **Maximum length (cm)**
<MAXLE>

9. **Length of socket (cm)**
<SOCLE>

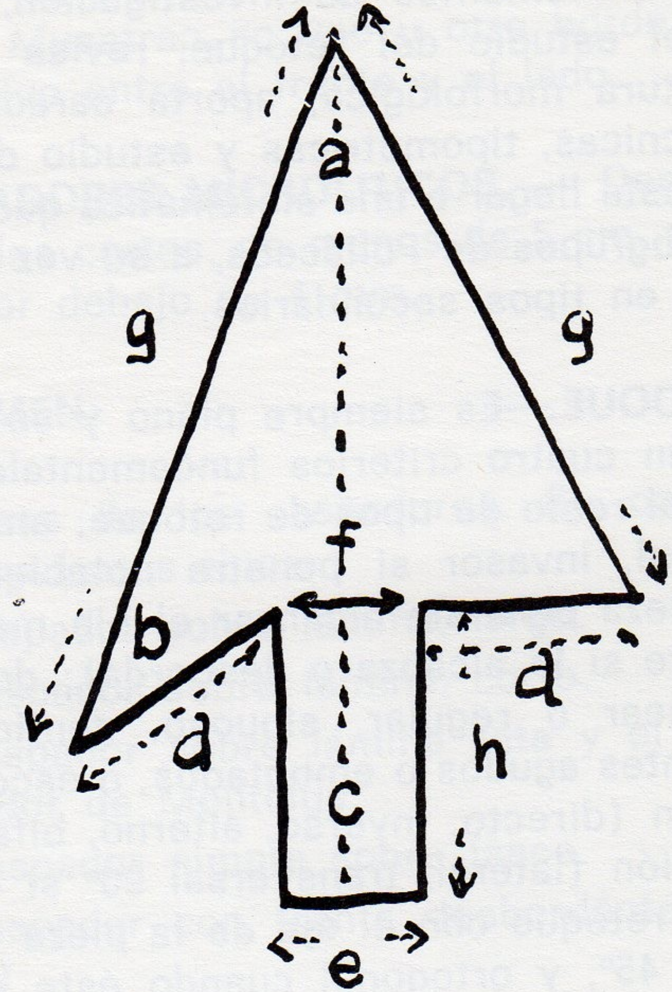
10. **Maximum width(cm)**
<MAXWI>

11. **Width of upper socket (cm)**
<UPSOC>

12. **Width of lower socket (cm)**
<LOSOC>

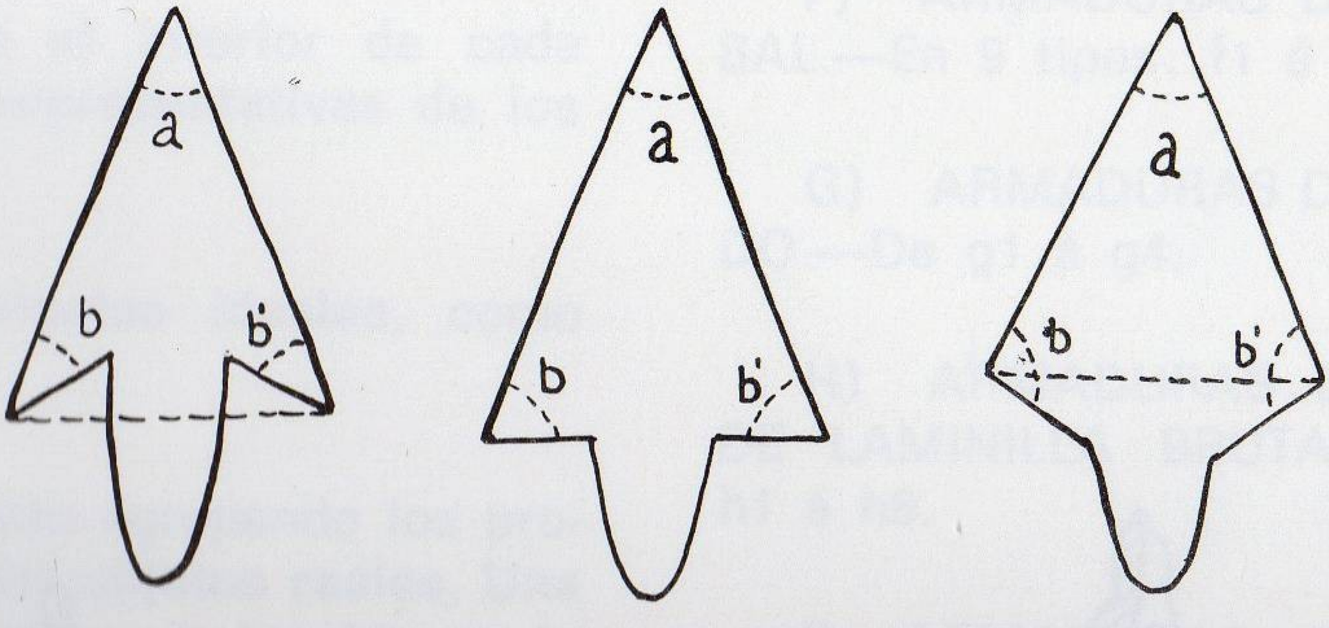
13. **Distance between maximum width and lower socket (cm)**
<MAWIT>

14. **Weight (g)**
<WEIGHT>



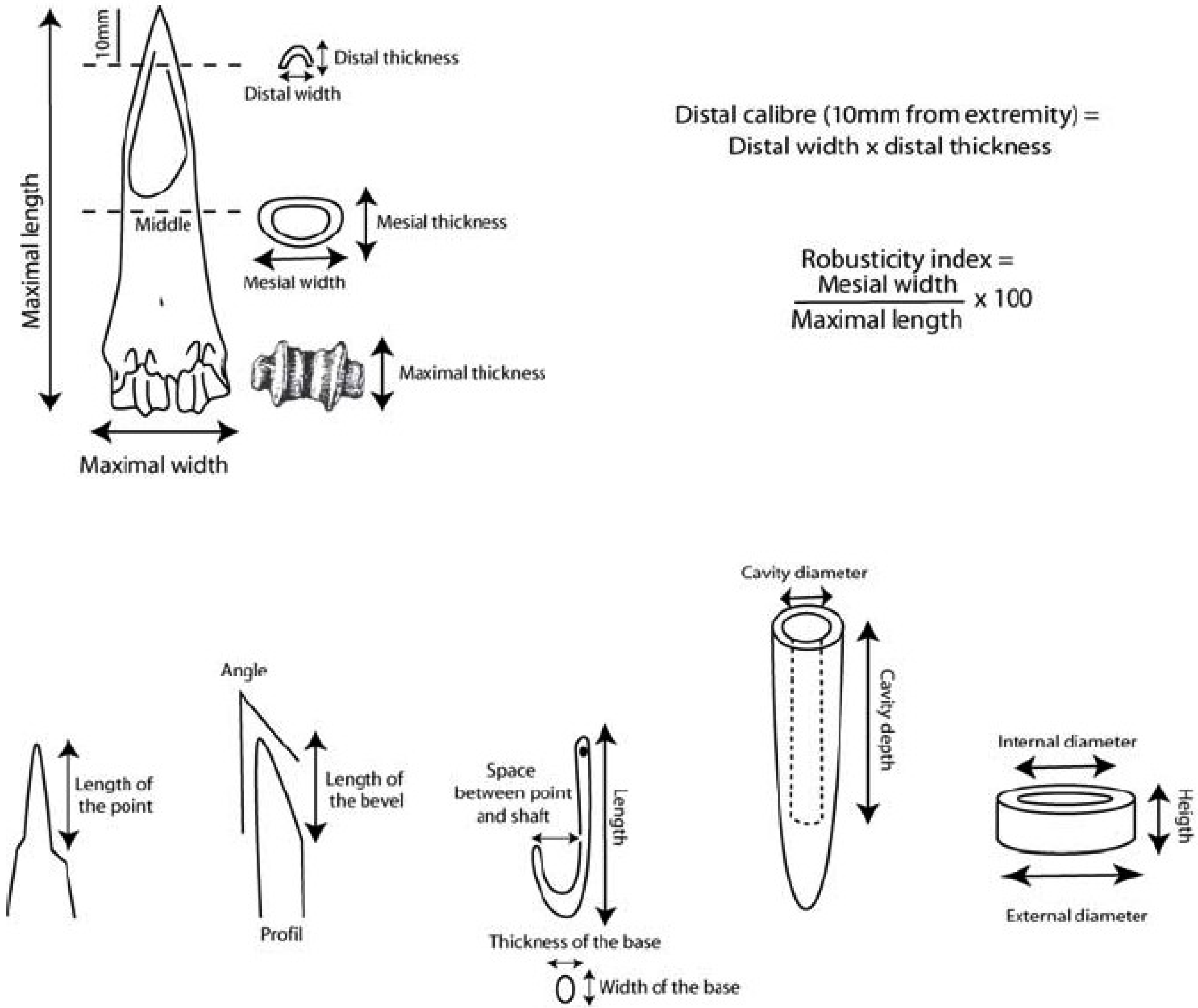
Nomenclatura morfológica:
a) Apice o punta. b) Alerón. c) Pedúnculo. d) Hombrera. e) Base del pedúnculo. f) Cuello. g) Borde lateral. h) Borde del pedúnculo, (de BAGOLINI).

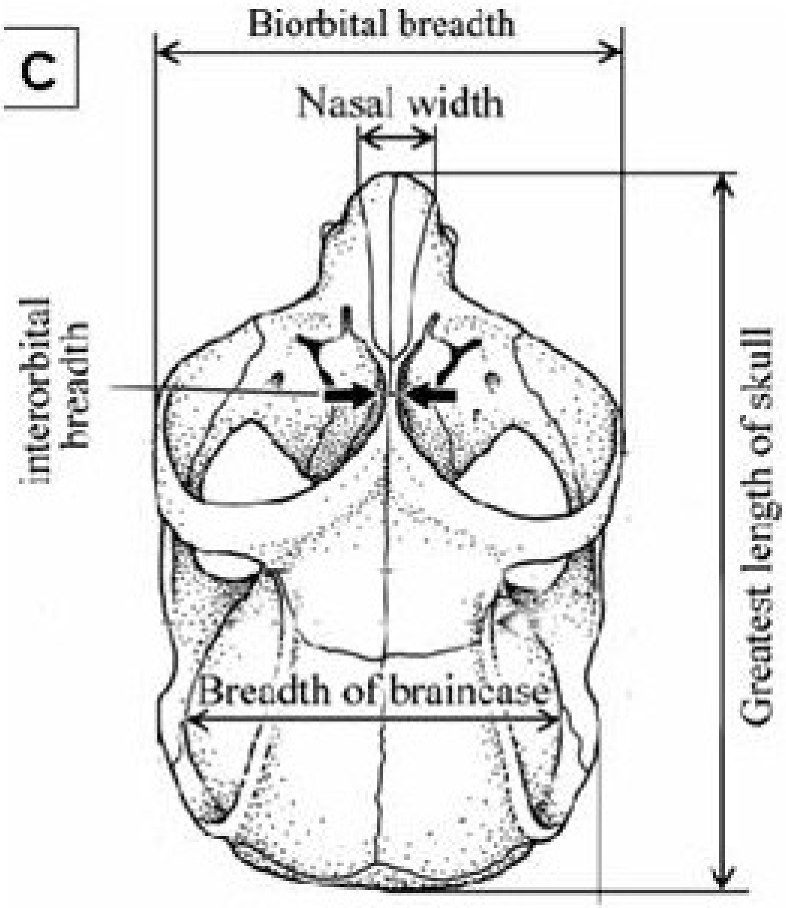
Fig. 300

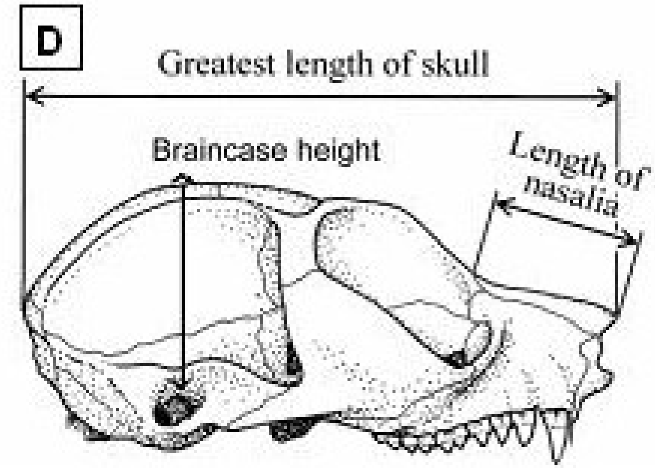


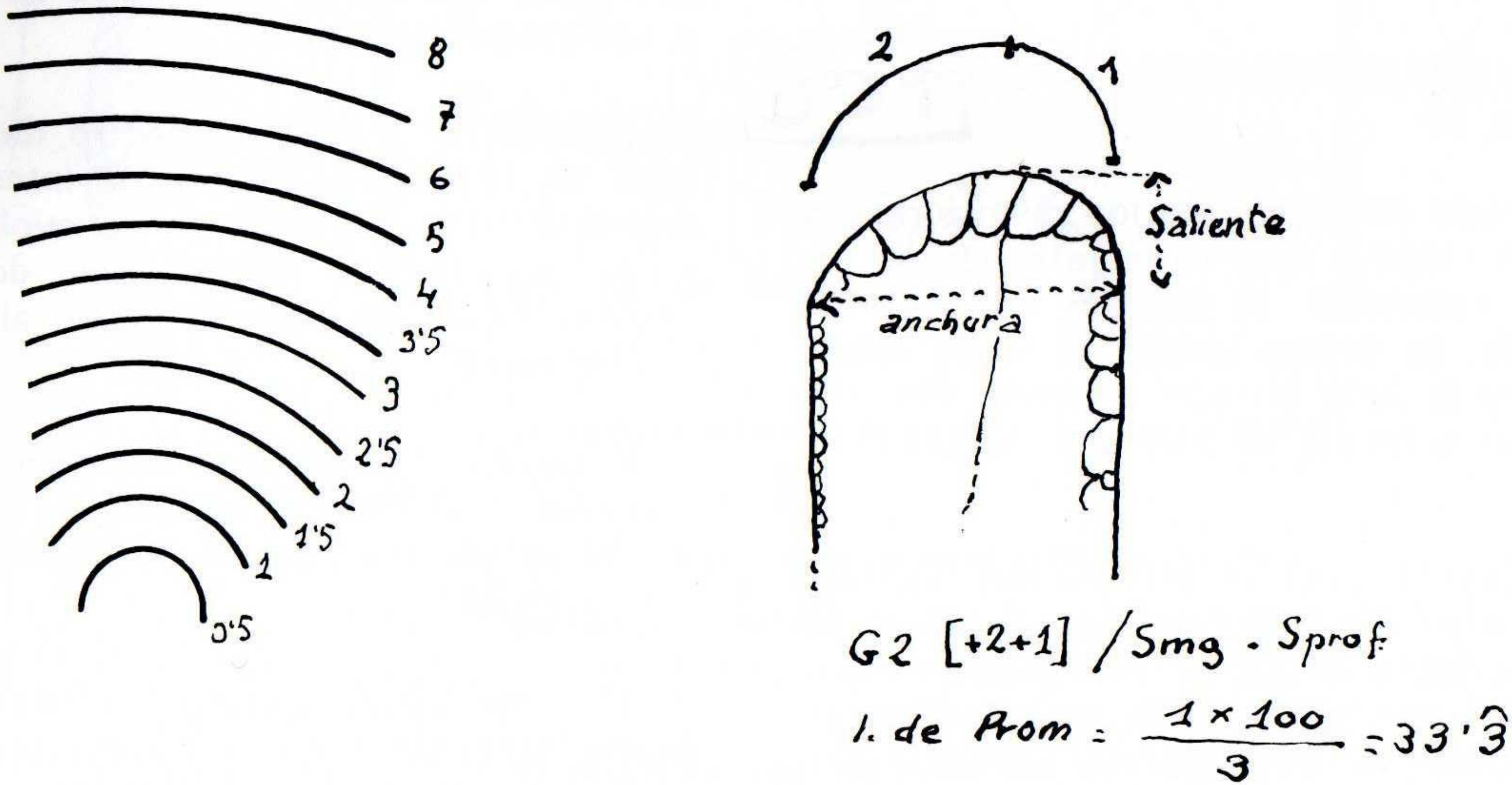
Tipos de alerones, según HUGOT
a: Agudos. b: Rectos. c: Obtusos
Fig. 335

Industria osea. Stordeur 1992




C
Biorbital breadth
Nasal width
interorbital breadth
Greatest length of skull
Breadth of braincase


D
Greatest length of skull
Braincase height
Length of nasalia

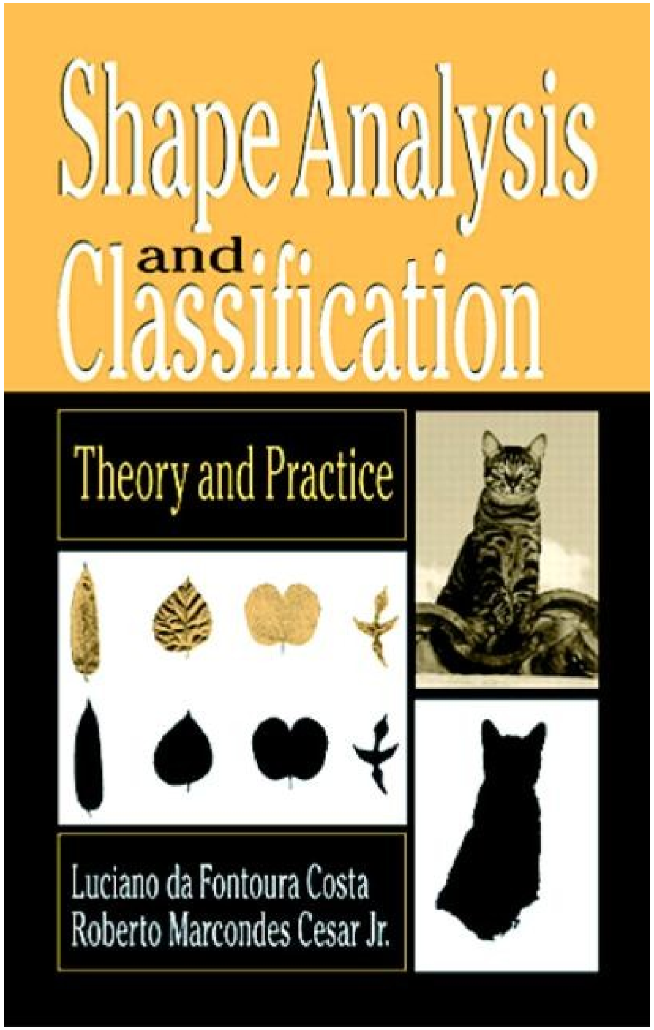


Curvas para medición de raspadores, y ejemplo de su aplicación a un raspador de frente mixto o complejo.

Fig. 378

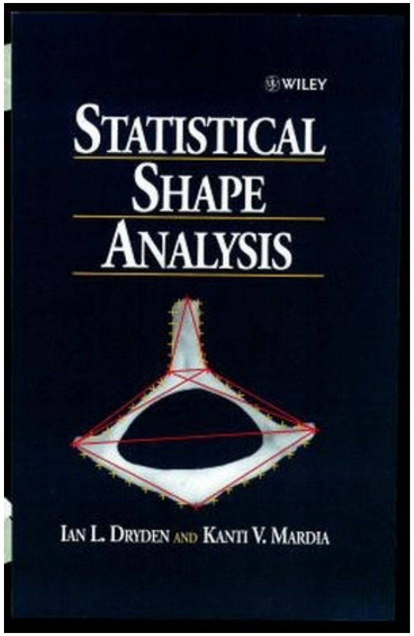
What is Shape?

- a shape can be understood as any “single”, “distinct”, “whole” or “united” visual entity.



What is Shape?

Properties of a configuration of points which are not altered for effects of size, position and orientation, or by translation, rotation and scaling



Describiendo el Perfil

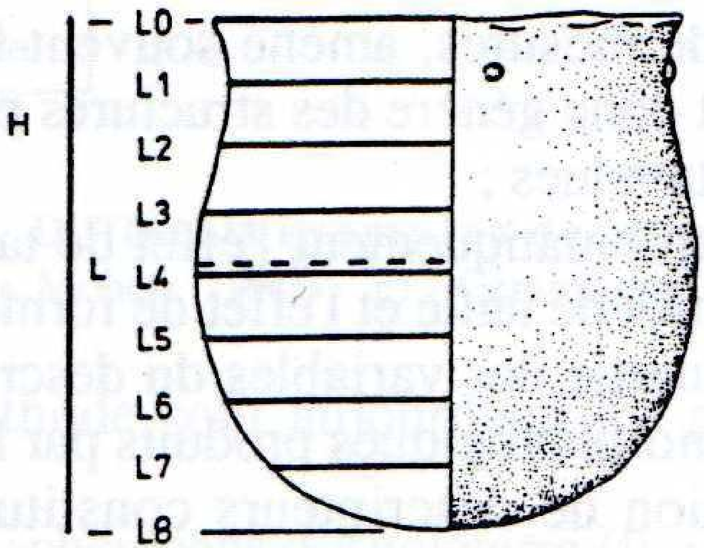


Fig. 6.2 : Échantillonnage de profil

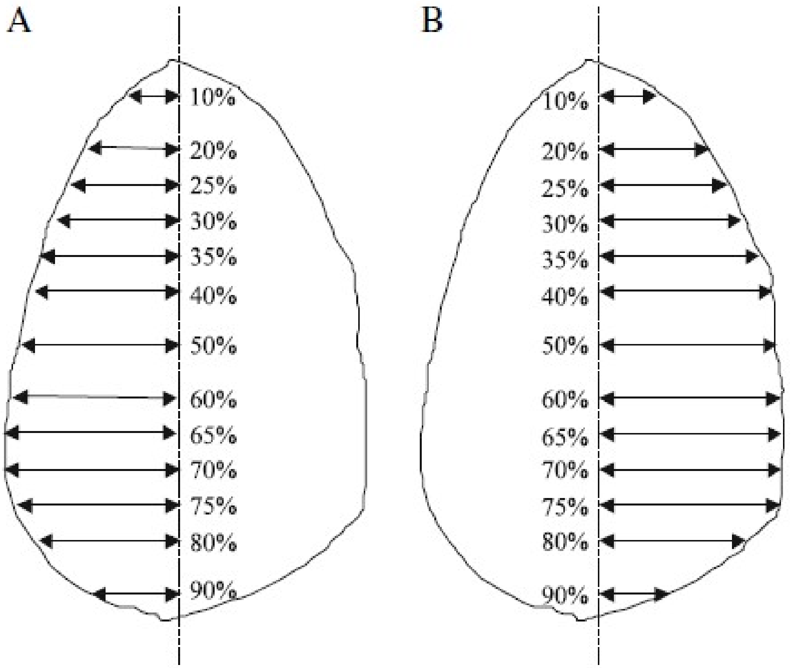


Fig. 6. Bilateral measurements taken from the length axis of the base. A total of 26 measurements were taken at percentage points left (A) and right (B) of this line.

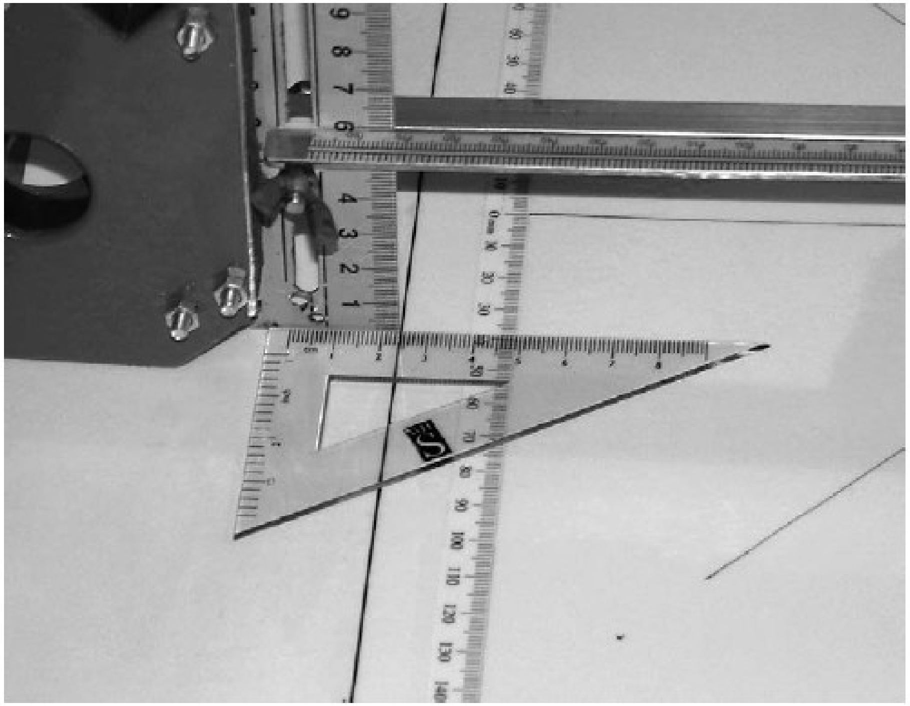


Fig. 7. Using setsquares to accurately align and position uprights along the scales of the base.

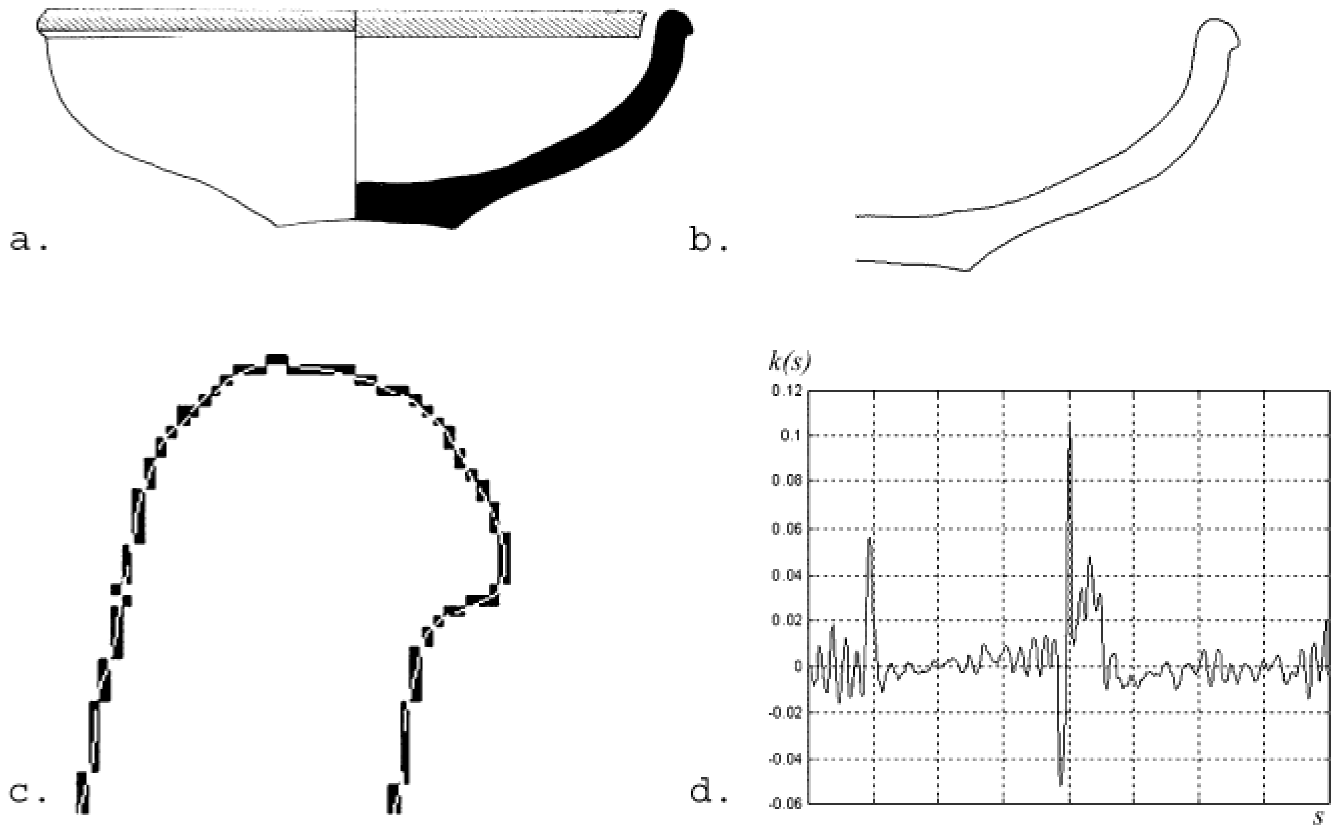
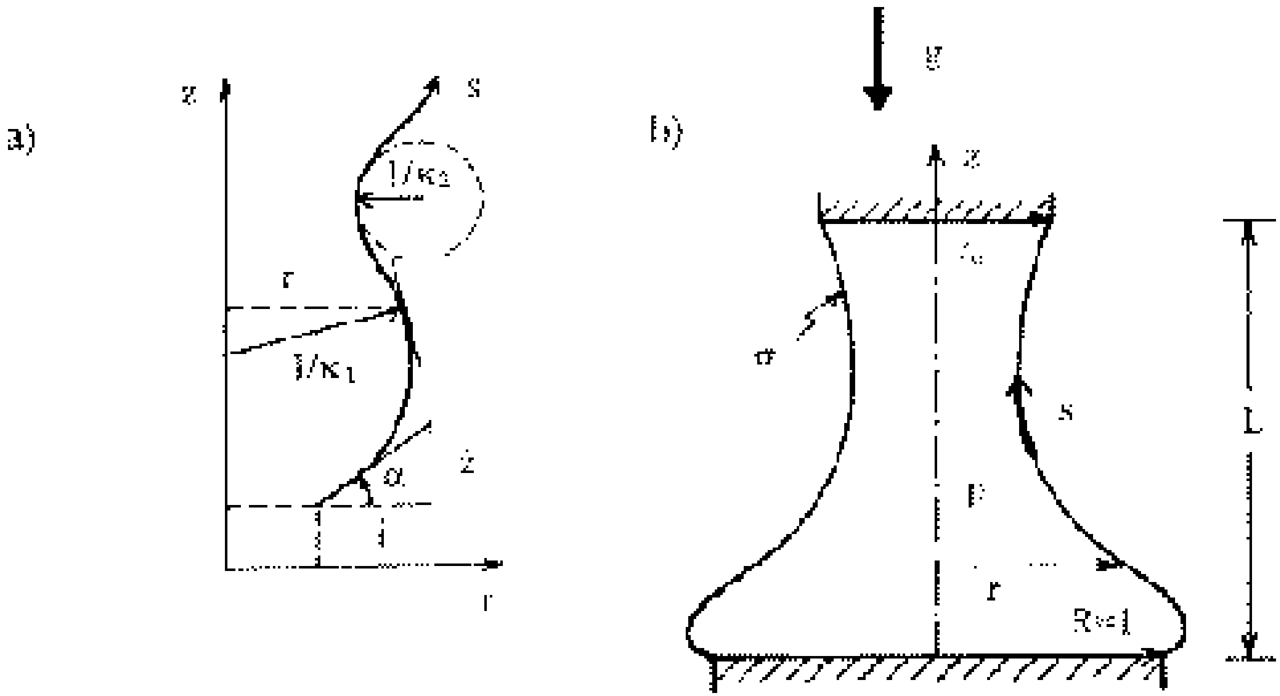
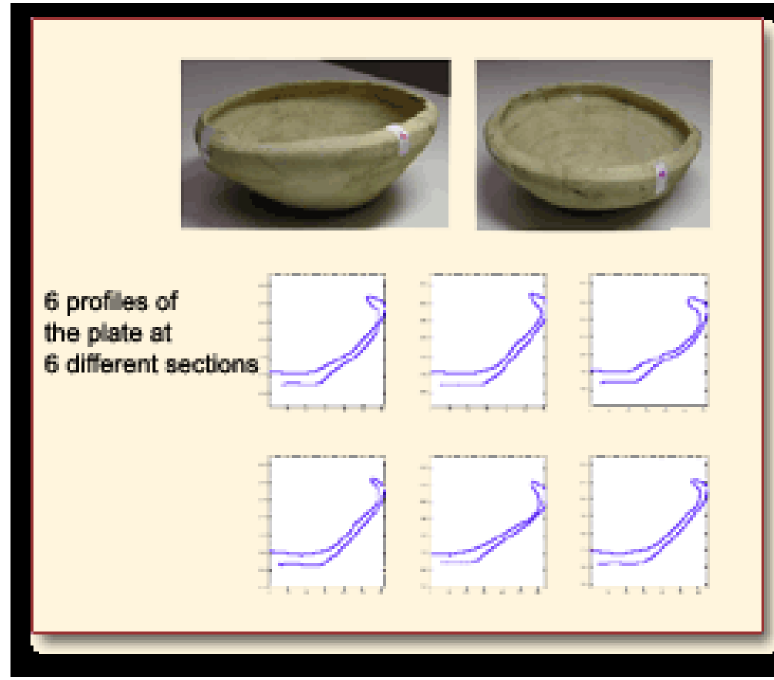


Fig. 1. The steps leading from a scanned drawing to the curvature function. a. A scanned drawing of a bowl. b. The pixelized profile. c. Enlarged detail of the pixelized profile and the interpolated curve. d. The curvature function.



a)
z
s
$1/\kappa_2$
r
$1/\kappa_1$
α
z
r
b)
g
z
σ
s
P
r
R=1
L



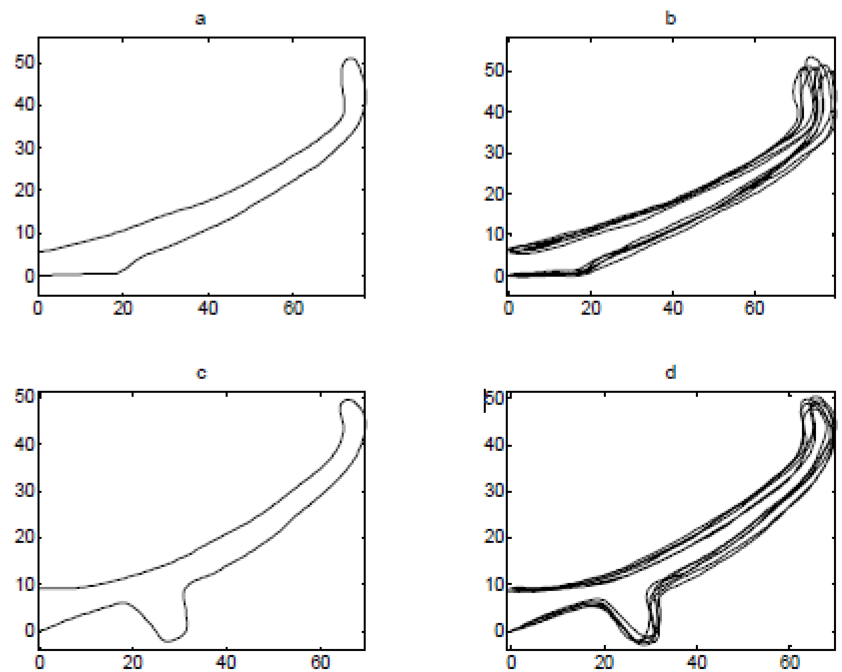


Fig. 1. Single profiles of two different bowls from Tell Dor, Israel (a,c and the overlap of six profiles of the same bowls (b,d), respectively

Relational Indexes

Circularity: the degree of circularity of a texel. That is how much this texel is similar to a circle. Where 1 is a perfect circle and 0.492 is an isosceles triangle. This shape is expressed by:

$$\frac{4\pi s}{p^2}$$

s: texel area
p: texel perimeter

Quadrature: the degree of quadrature of a texel, where 1 is a square and 0.800 an isosceles triangle. This shape is expressed by:

$$\frac{p}{4\sqrt{s}}$$

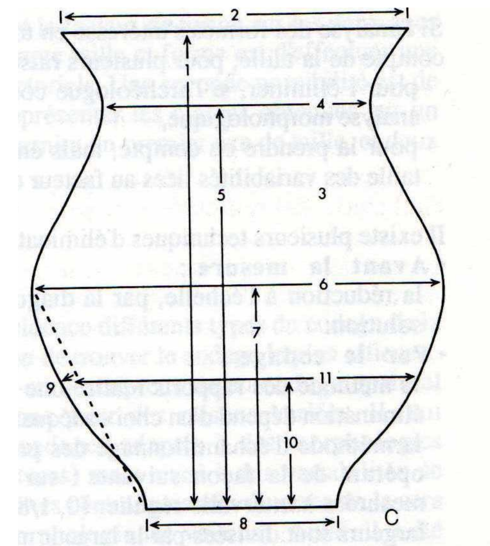
Irregularity: measurement of the irregularity of a texel, done with its perimeter and the perimeter of the surrounding circle. The minimum irregularity is a circle, corresponding at the value 1. A square is the maximum irregularity with a value of 1.402. This shape is expressed by:

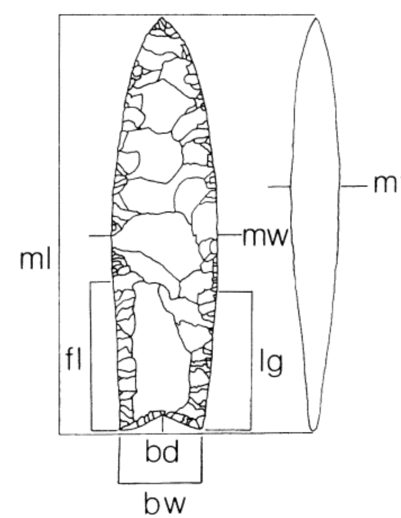
$$\frac{p_c}{p}$$

Elongation: as the degree of ellipticity of a texel. Where a circle and a square are the less elliptic shape. This shape is expressed by:

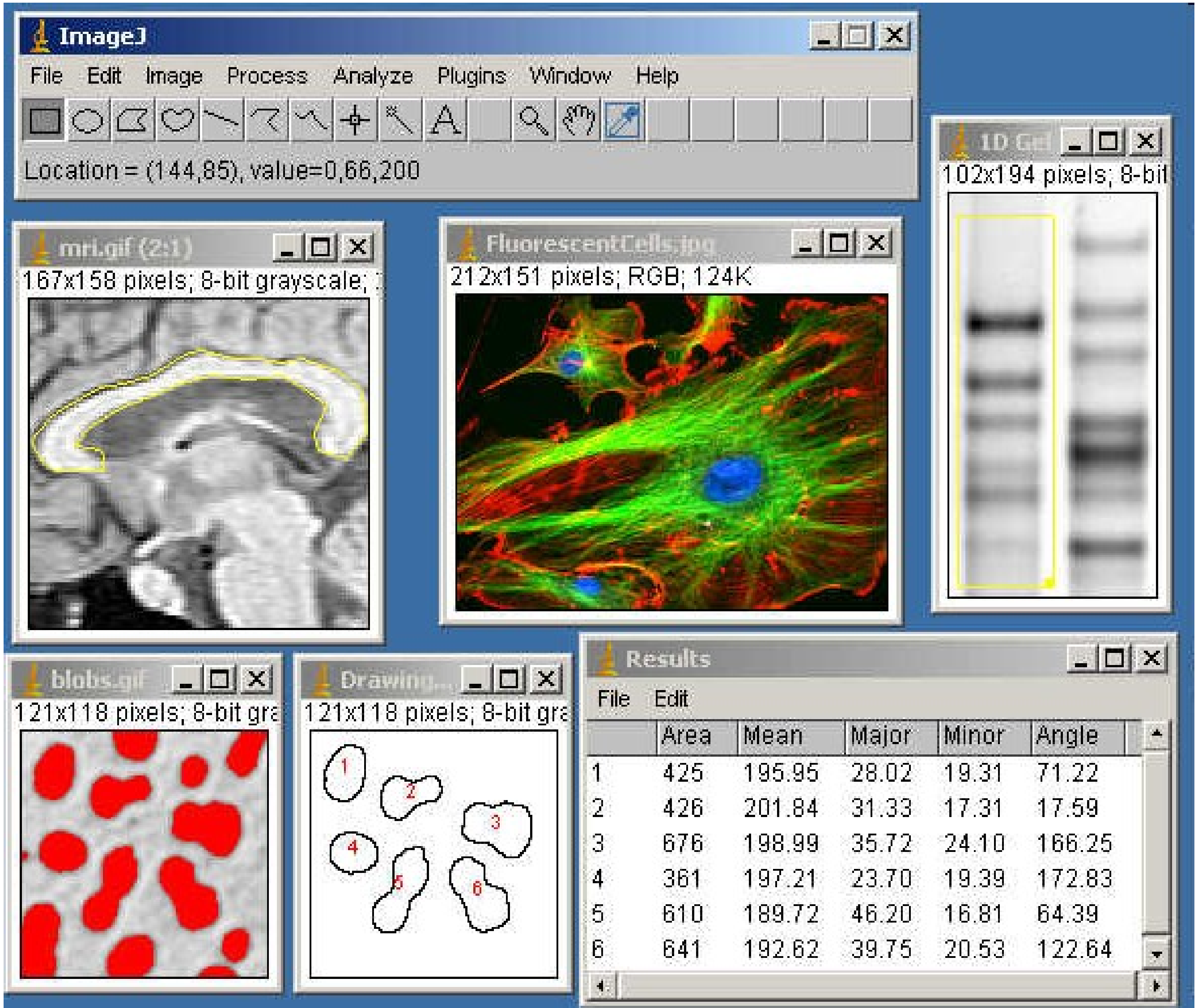
$$\frac{D}{d}$$

D: maximum diameter within a texel
d: minimum diameter perpendicular at D

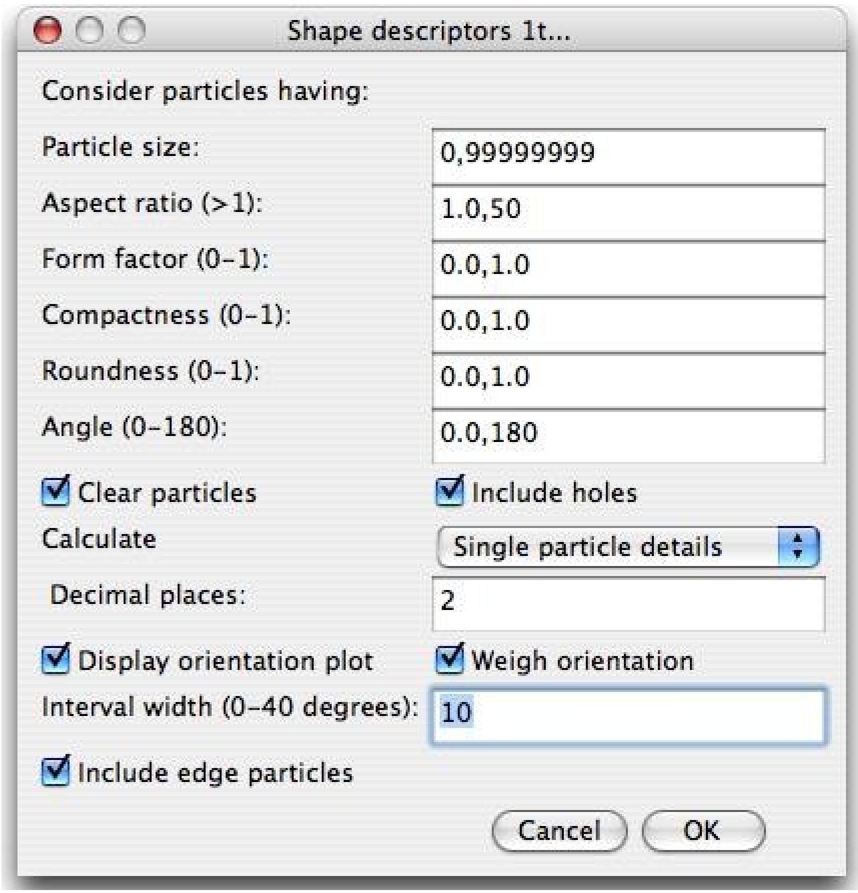


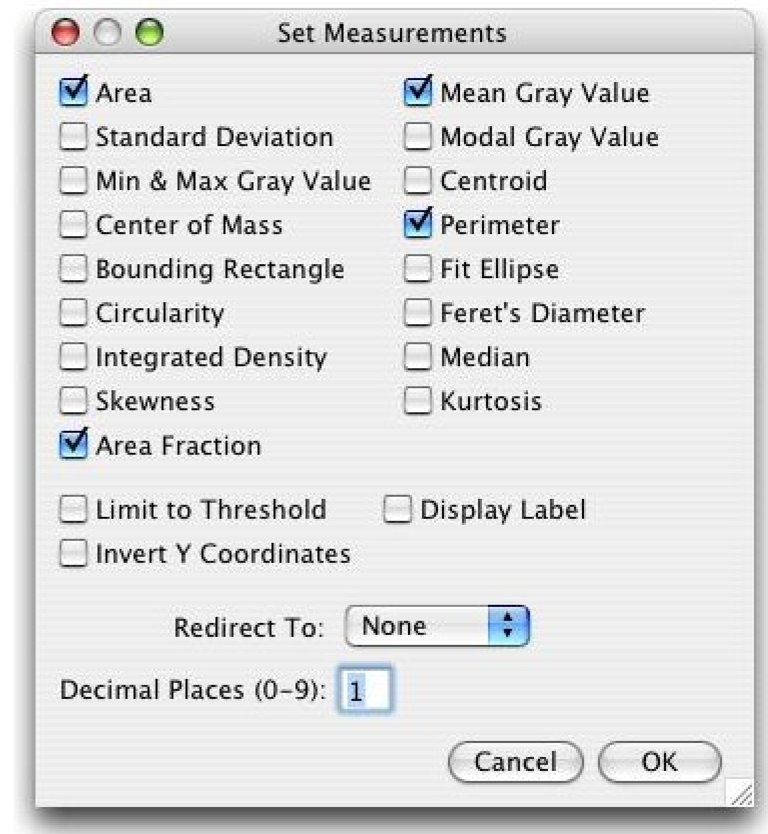


ImageJ. http://rsb.info.nih.gov/ij/



ImageJ. http://rsb.info.nih.gov/ij/ FiJi is Just ImageJ. http://fiji.sc/Fiji

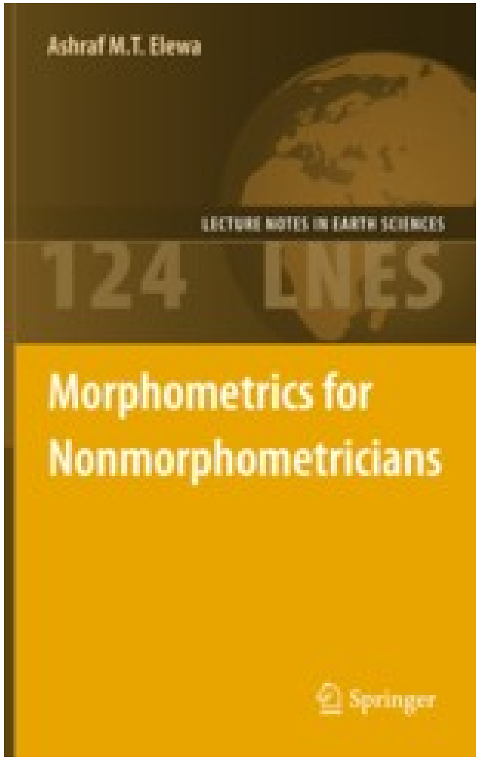




Measuring Shape

An ordered *n*-tuple of measurements completely characterizes a shape without redundancy if (a) there is a set of drawing rules that permits reconstruction of the shape outline using only this ordered *n*-tuple of measures, and (b) there is no ordered *k*-tuple of measures, $k<n$, such that the shape outline can be reconstructed from the ordered *k*-tuple (Read 2007).

Morphometrics

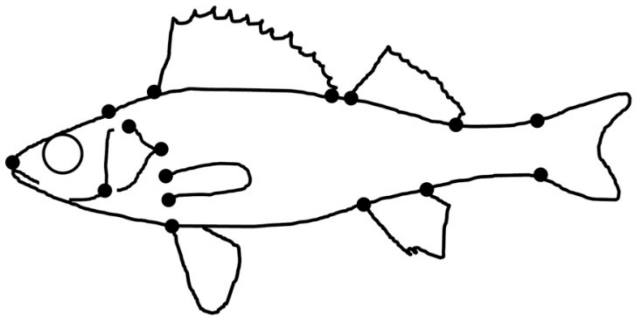


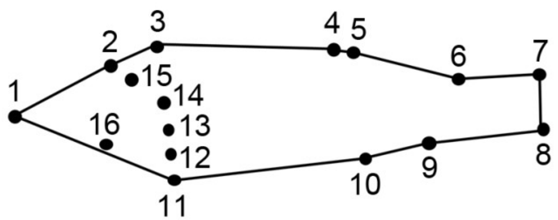
Landmark-based geometric morphometrics: summarises shape in terms of landmark configuration (discrete anatomical loci, described by two-/three-dimensional Cartesian co-ordinates);

Outline-based geometric morphometrics: summarises the shape of open or closed curves, typically without fixed landmarks. Analyses include Fourier (Elliptical Fourier, Fast Fourier etc.) and Eigenshape (and Extended Eigenshape) analyses

ArchaeoMorph

www.archaeologicalmorphometrics.com



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259 167
260 305
259 388
445 395
403 263
308 45
297 168
222 168
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118 264
76 394
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LM=13
192 6
188 88
188 111
191 164
192 206
370 158
294 156
220 27
211 111
171 111
165 29
96 157
15 156
ID=Benneviaspis_lankesteri
LM=13
161 23
```

Morphometrics, the practical side

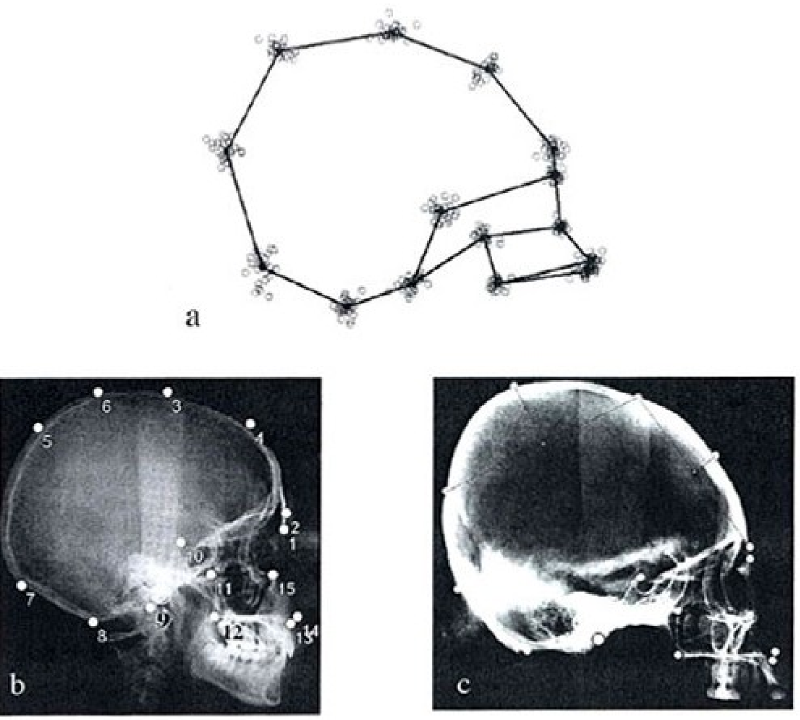
tpsUtil and tpsDig programs from Rohlf's morphometrics site

http://life.bio.sunysb.edu/morph/

Point Picker plugin for ImageJ
http://bigwww.epfl.ch/thevenaz/pointpicker/

MorphJ. Manchester University

http://www.flywings.org.uk/morphoj_page.htm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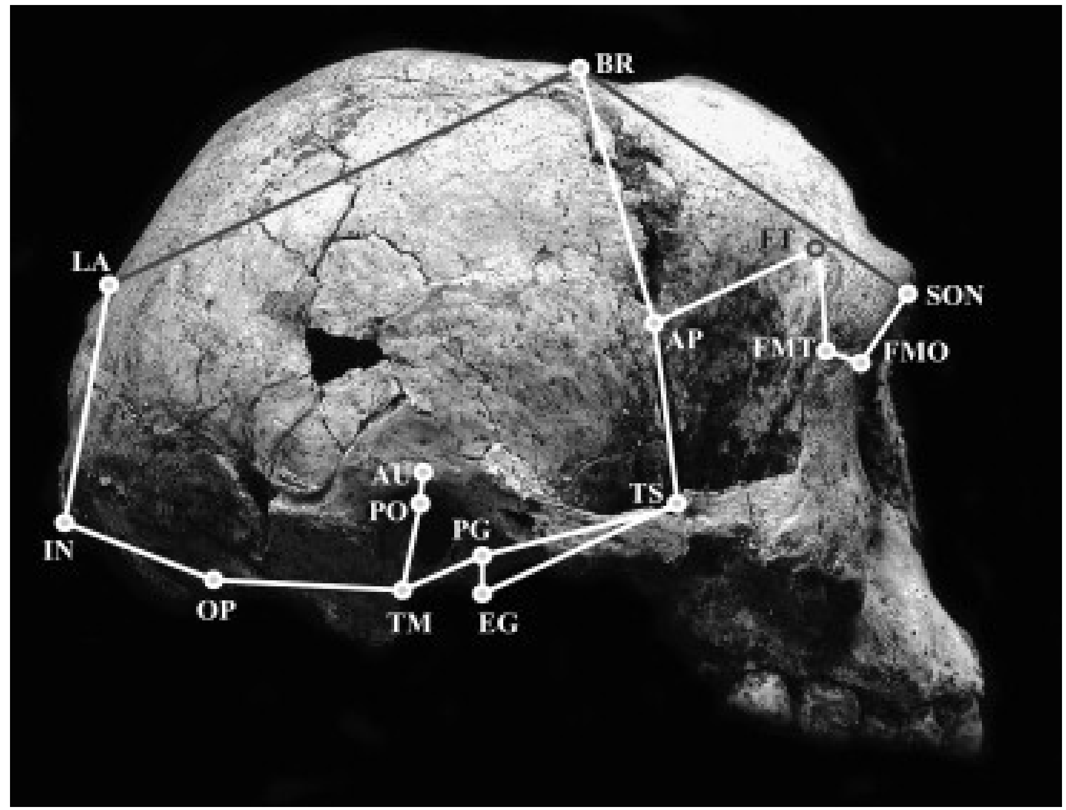
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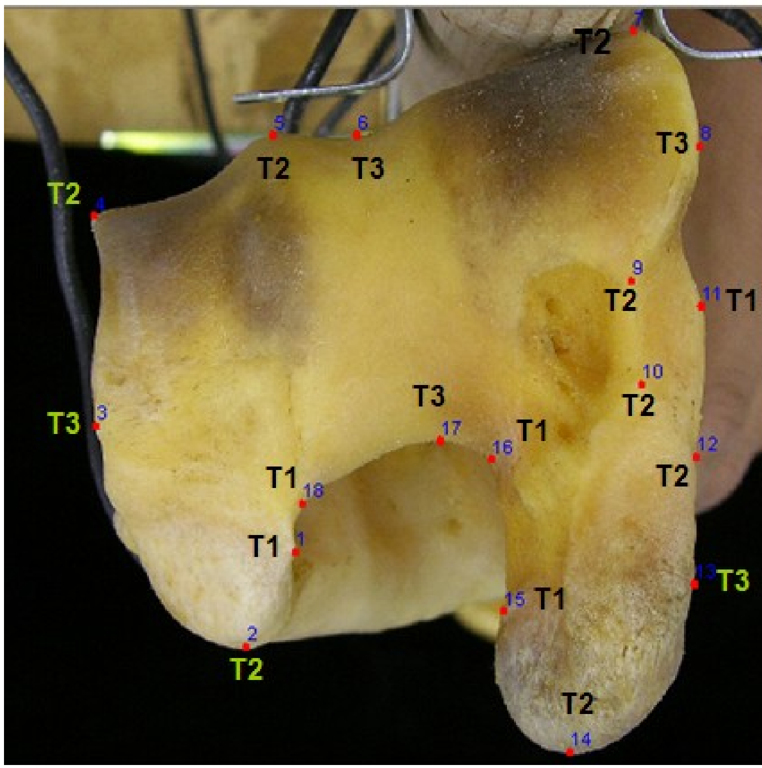
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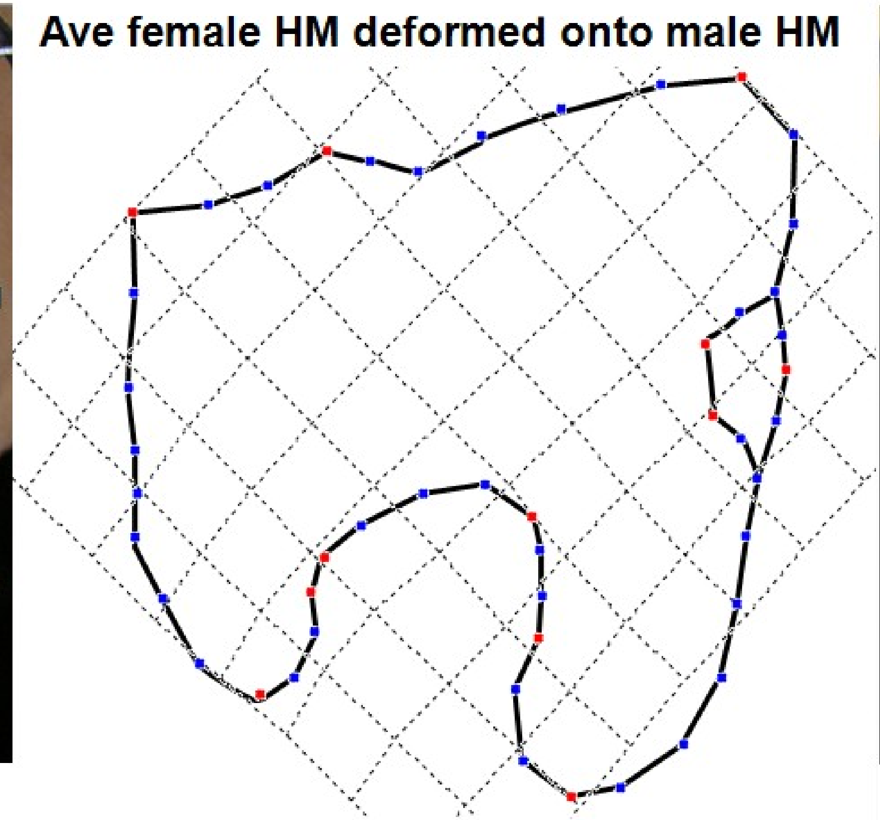
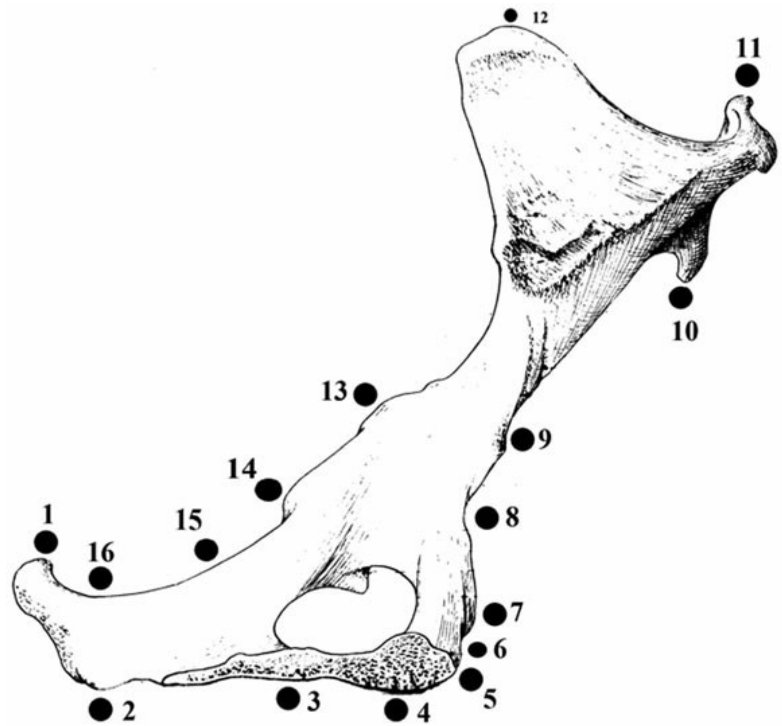

Ave female HM deformed onto male HM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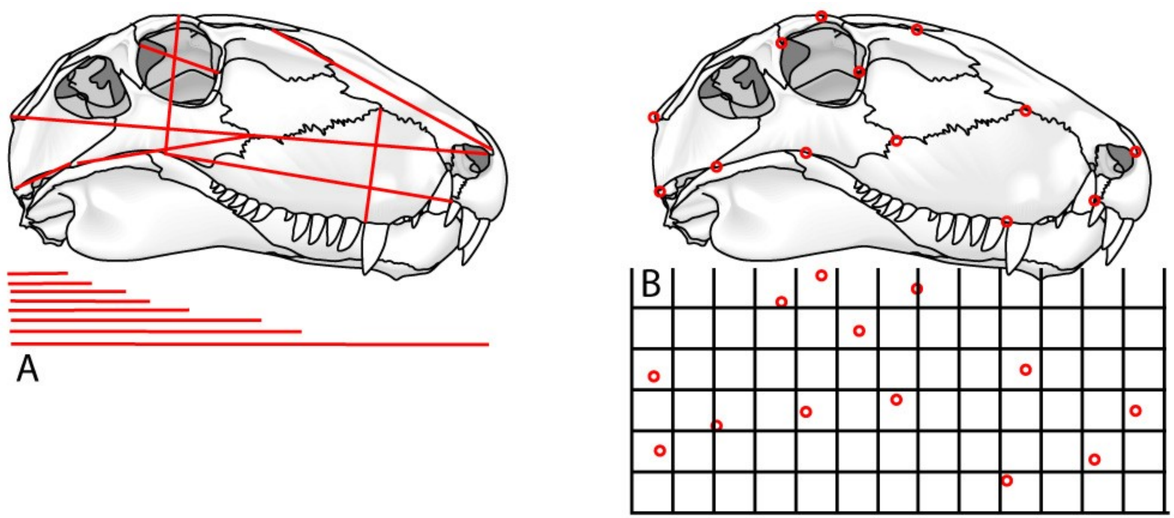
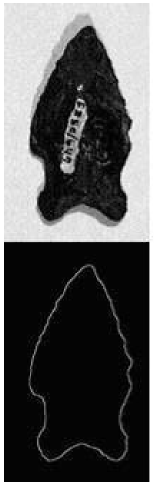
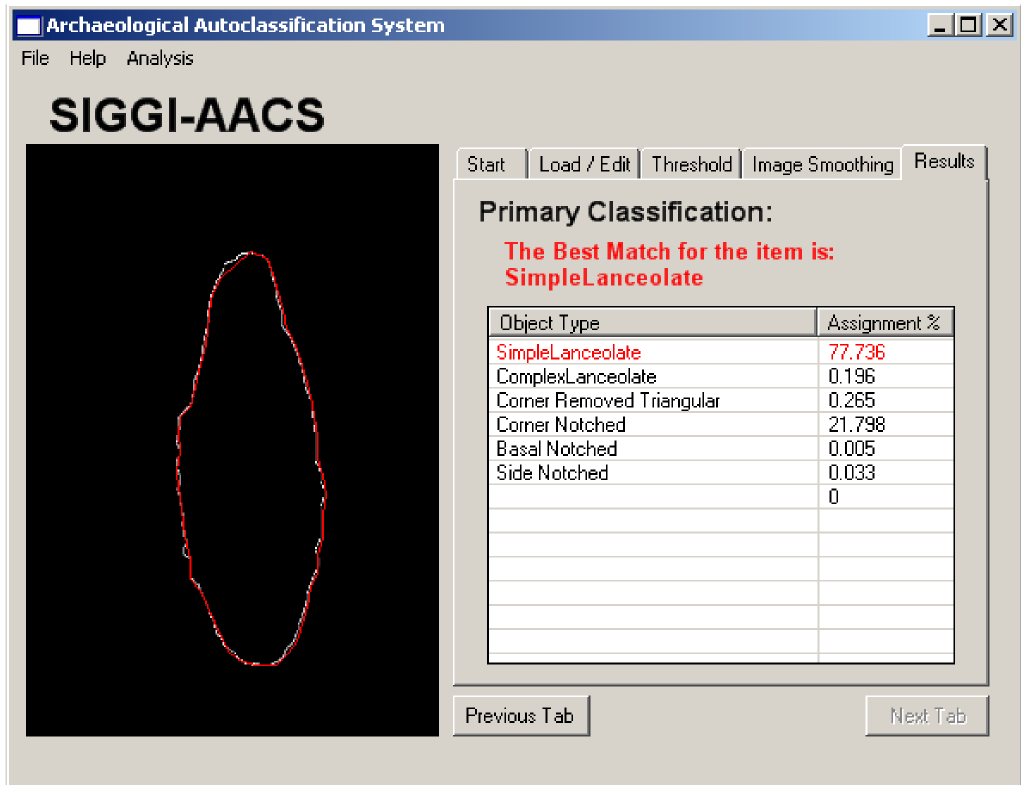

A
B

LOHSE, E.S., SCHOU,C., SCHLADER,R., SAMMONS,D, 2004, “Automated Classification of Stone projectile Points in a Neural Network”. In *Enter the Past. The e-way into the four dimensions of culture heritage*. Edited by Magistrat der Stadt Wien-Referat Kulturelles Erbe-Städtarhchäologie Wien. Oxford, ArcheoPress (B AR Int. Series, S1227), pp. 431-437).





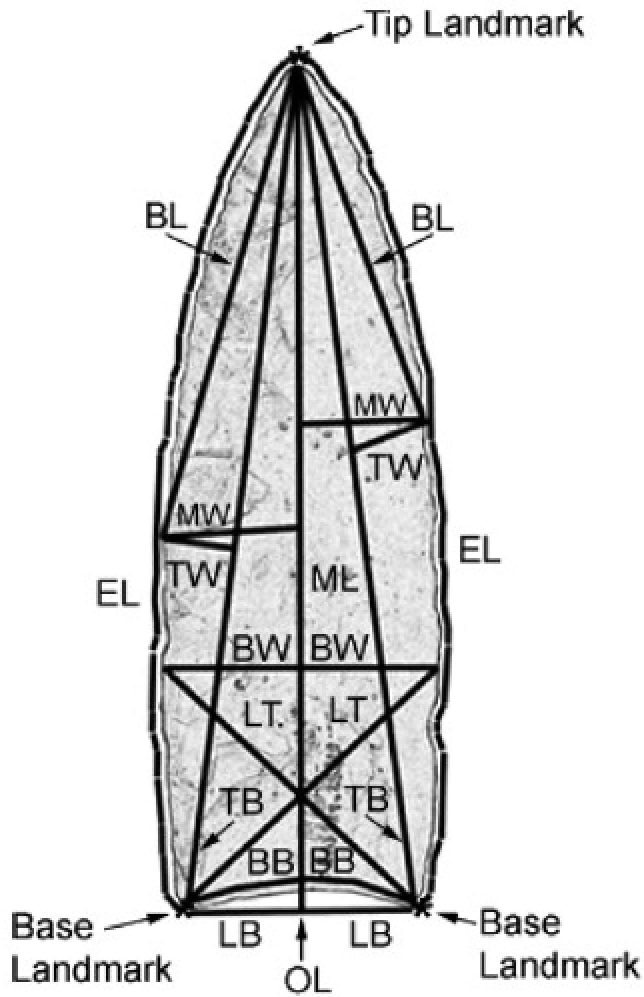
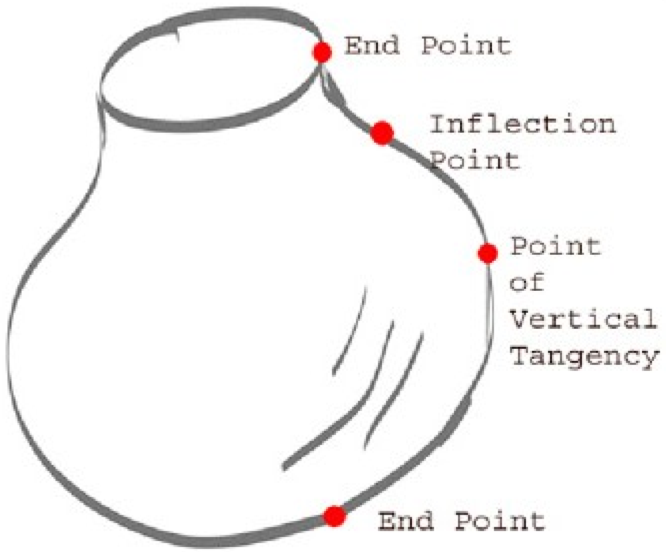


Fig. 3. Image of Clovis point showing approximate location where 11 interlandmark characters are measured and the location of the three landmarks. Character initials: EL, edge boundary length; TB, tip landmark to base landmark; TW, width of tip to base length to maximum inflection position; BL, blade length; MW, maximum width; BB, base boundary length; LB, linear measure of base; ML, midline length; OL, overall length; BW, basal width across first third of point; LT, length from base to 1/3 along opposite edge.



End Point
Inflection Point
Point of Vertical Tangency
End Point

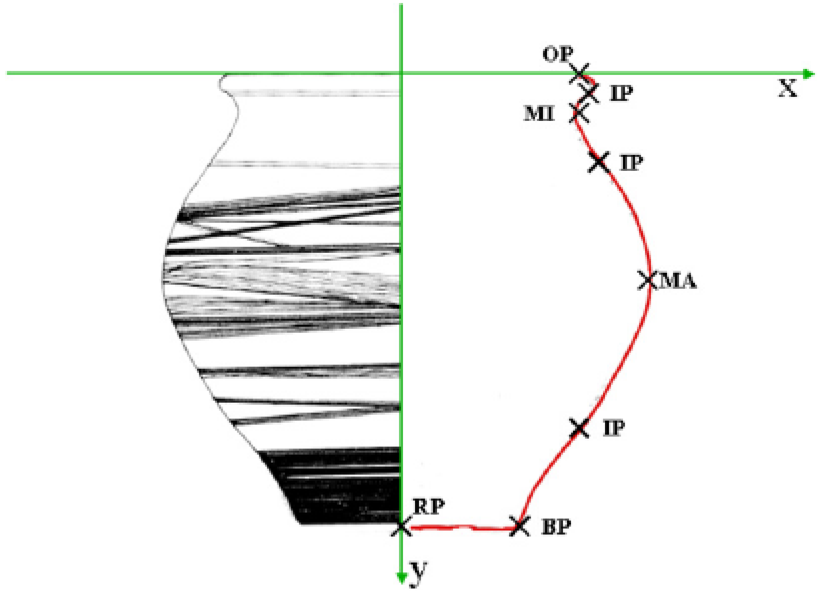
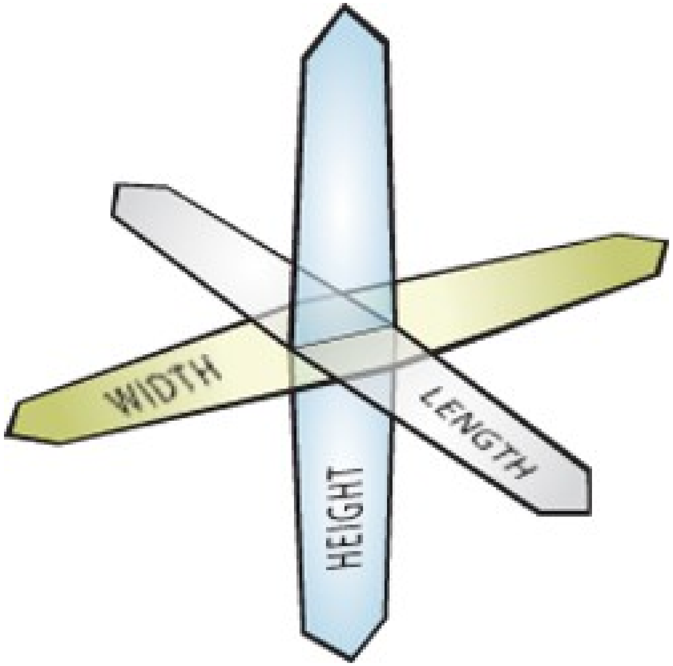
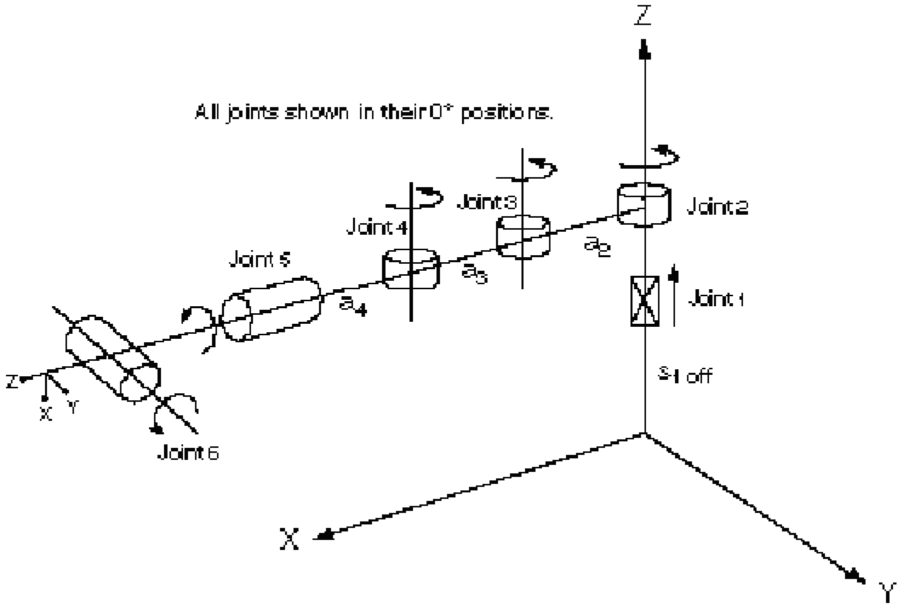


Fig. 8. S-shaped vessel: profile segmentation scheme.

- MI, local minimum: point of vertical tangency; point where the x-value is smaller than in the surrounding area of the curve.
- MA, local maximum: point of vertical tangency; point where the x-value is bigger than in the surrounding area of the curve; the y-value refers to the height of the object (e.g. MA(y)).
- CP, corner point: point where the curve changes its direction substantially.
- BP, base point: outermost point, where the profile line touches the base plane.
- RP, point of the axis of rotation: point where the profile line touches the axis of rotation.
- EP, end point: point where the profile line touches the axis of rotation; applied to incomplete profiles.

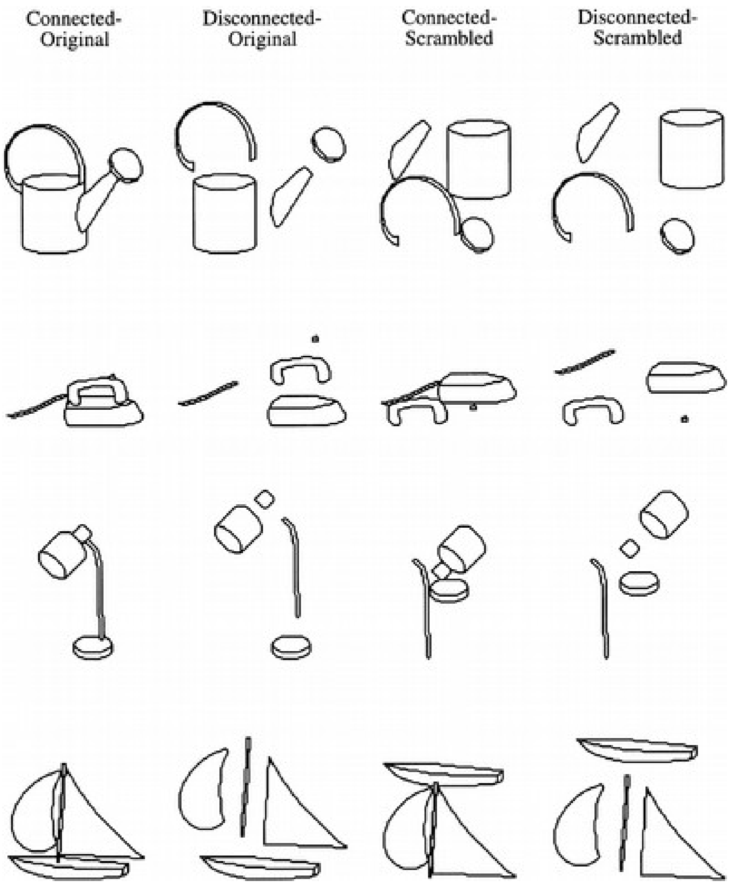
3 dimensionality of Physical Space

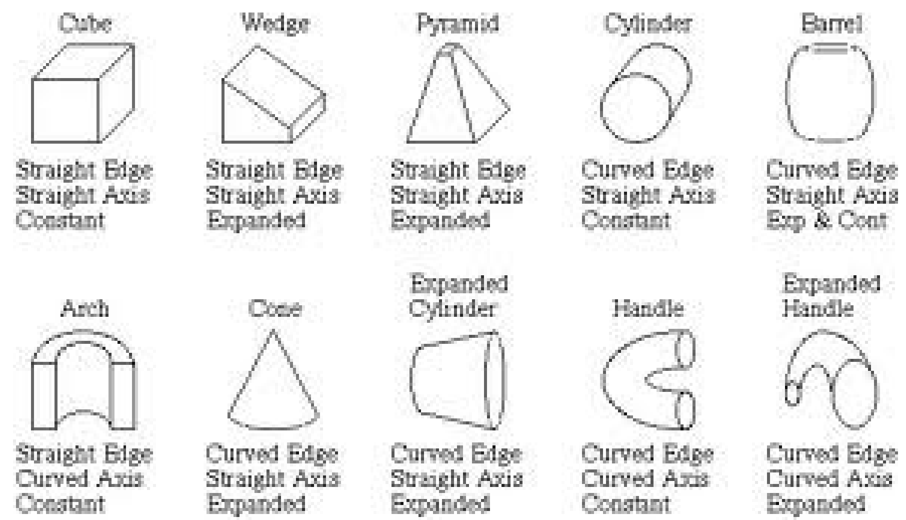




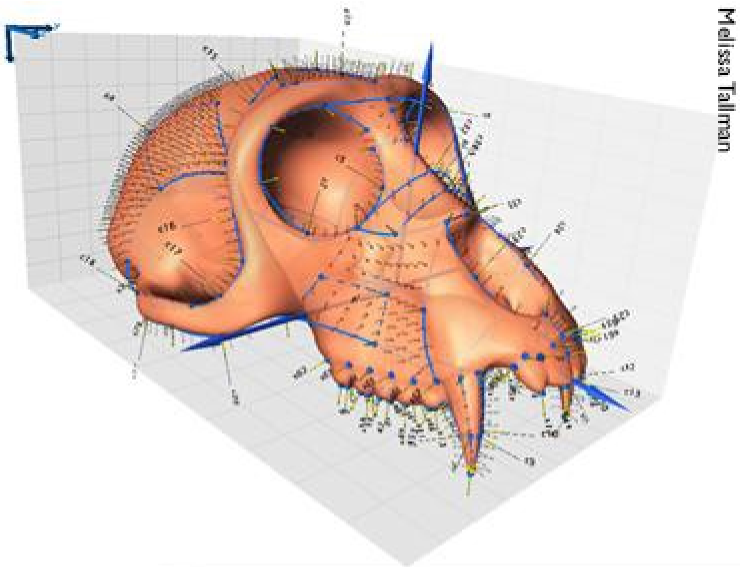
SHAPE DECOMPOSITION

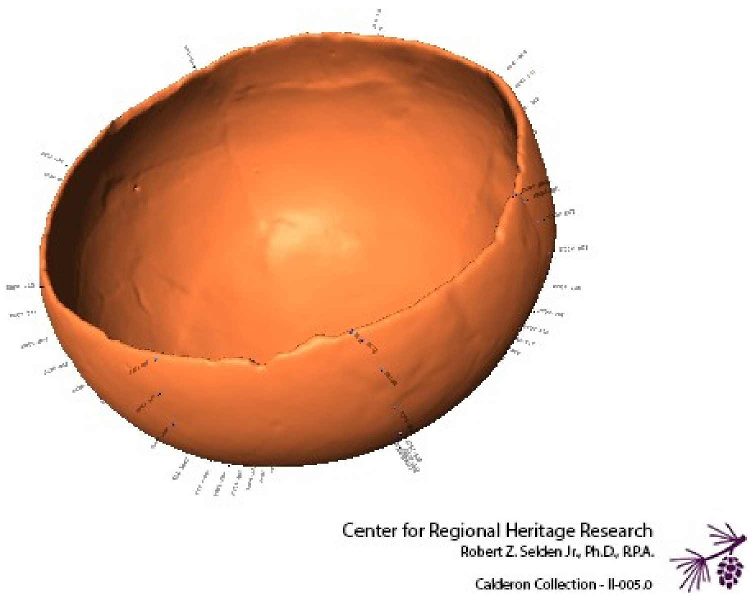
Geon Theory (Biederman 1987)

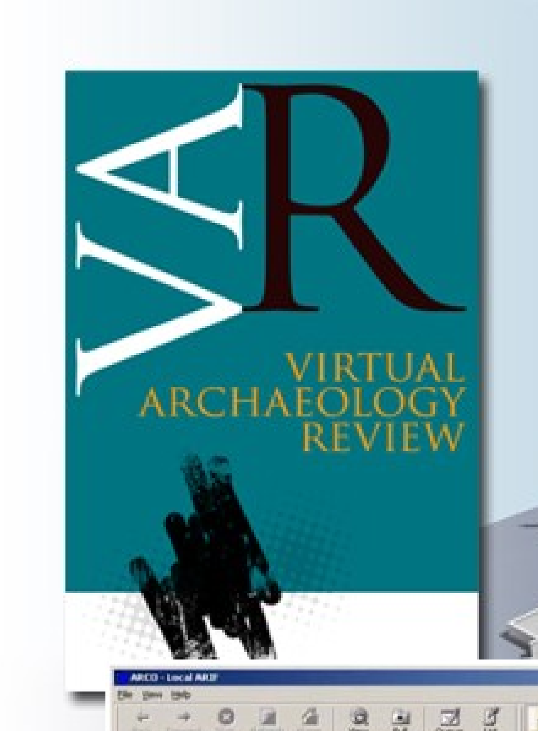




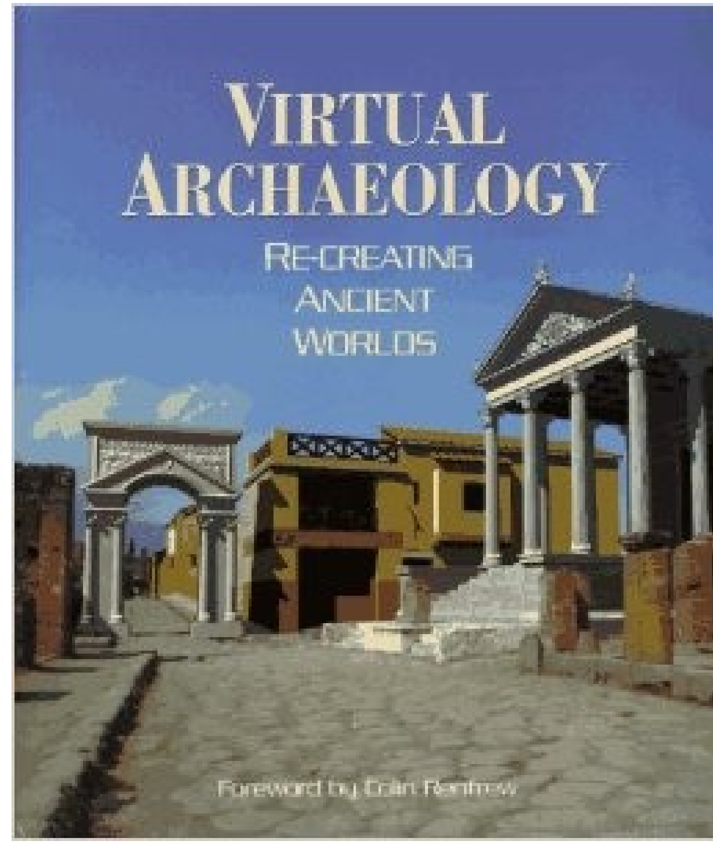
3D Morphometrics






VAR
VIRTUAL
ARCHAEOLOGY
REVIEW


D E F G J K L P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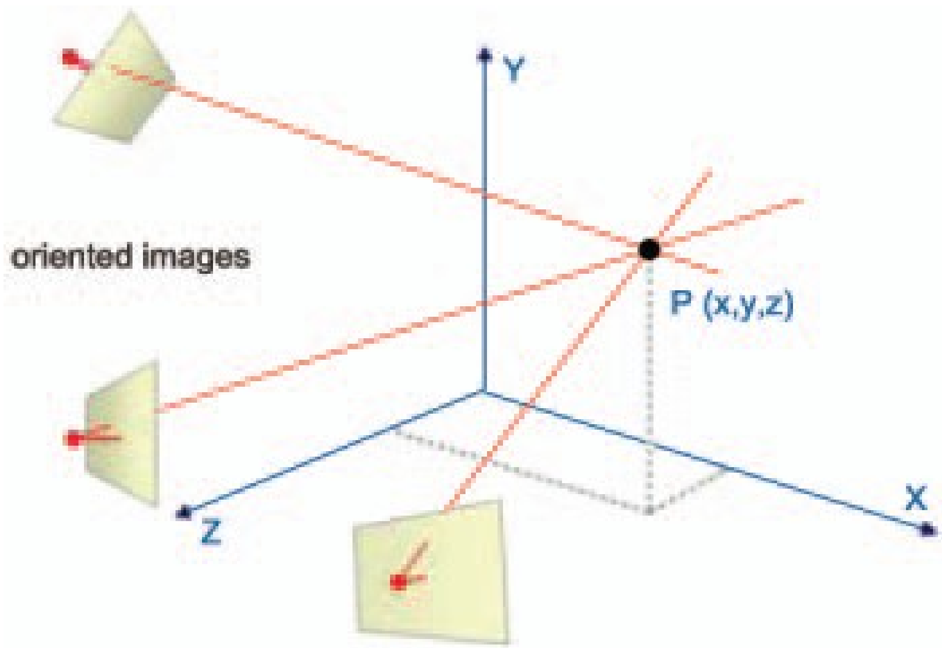
ARCHAEOLOGY
RE-CREATING
ANCIENT
WORLDS
Foreword by Colin Renfrew

Photogrametry



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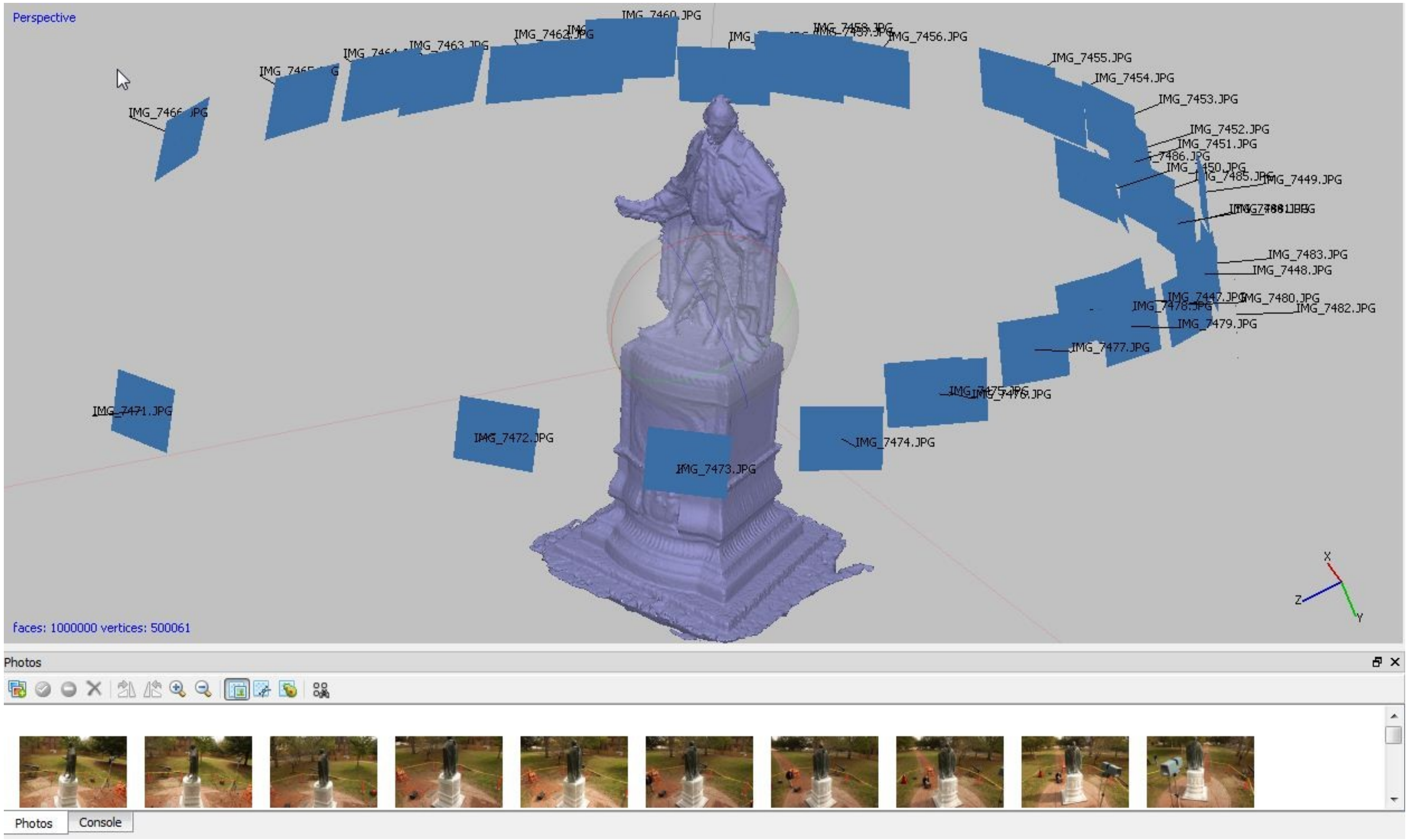

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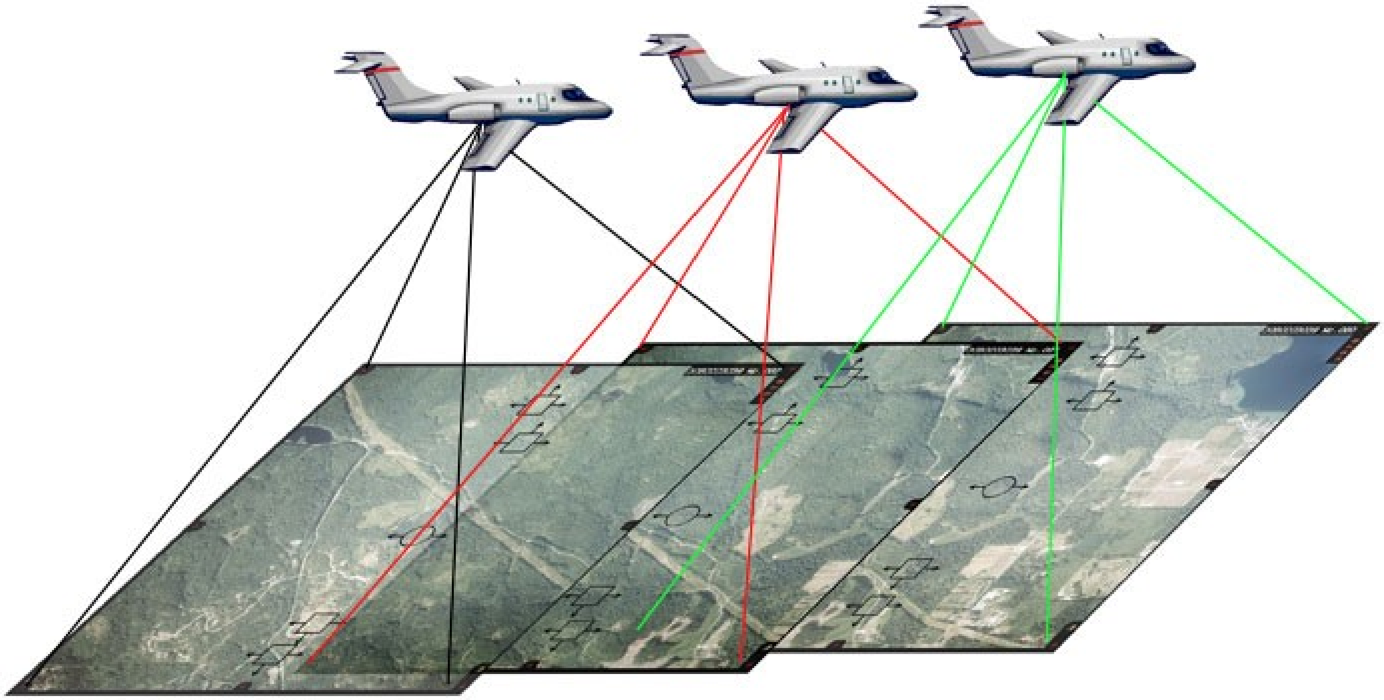
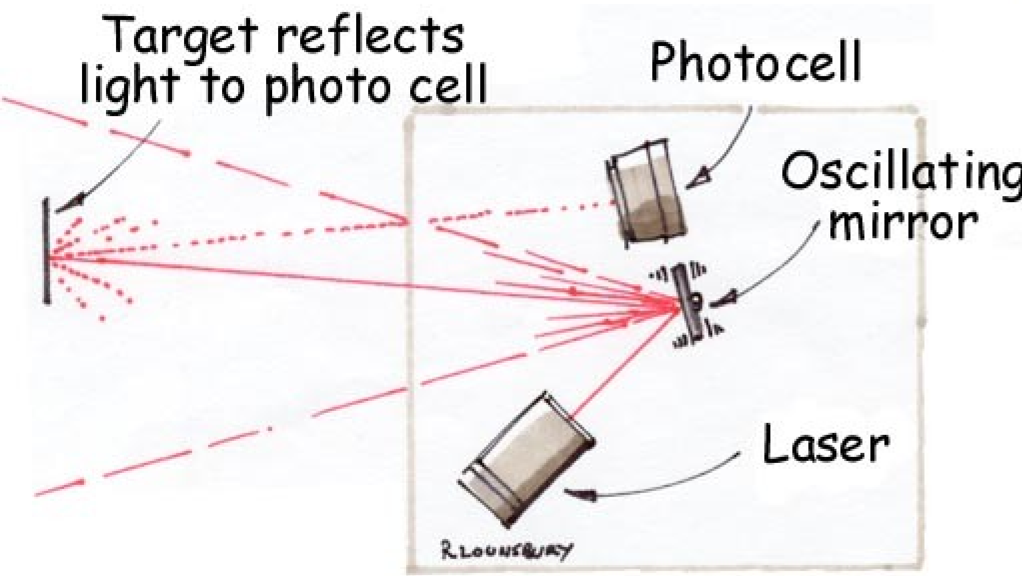


3D Scanning

3D Scanning /



Target reflects
light to photo cell
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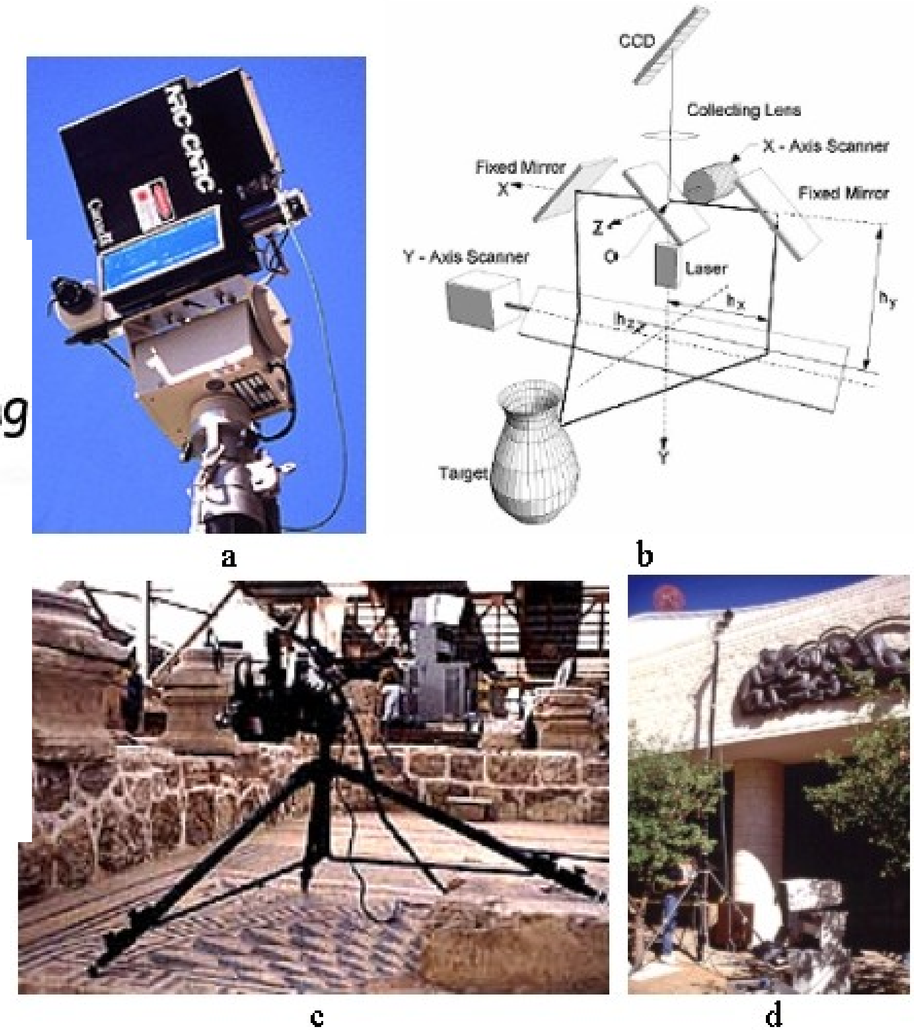

CCD
Collecting Lens
X - Axis Scanner
Fixed Mirror
Fixed Mirror
Y - Axis Scanner
Laser
Target
a
b
c
d

3D Scanning

3D Scanning

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Institució Milà i Fontanals
(CSIC)

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UAB-CVC

3D Scanning


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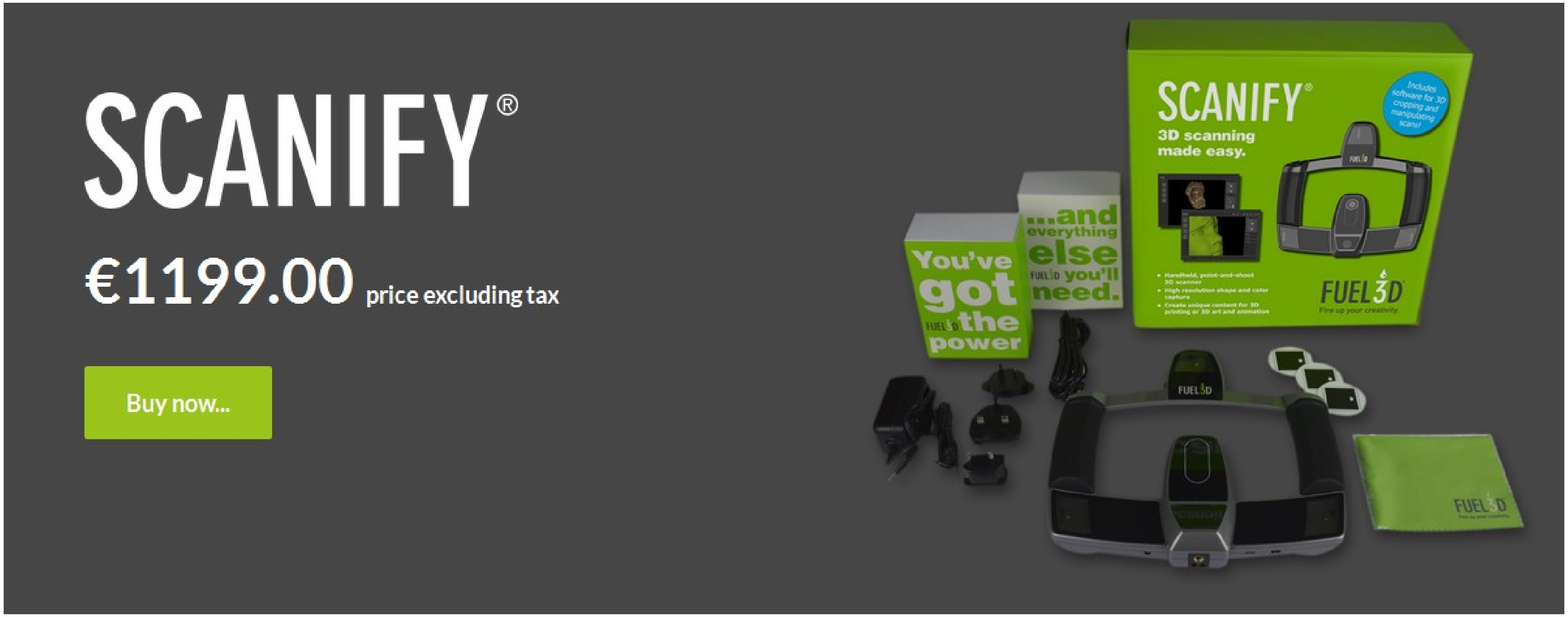
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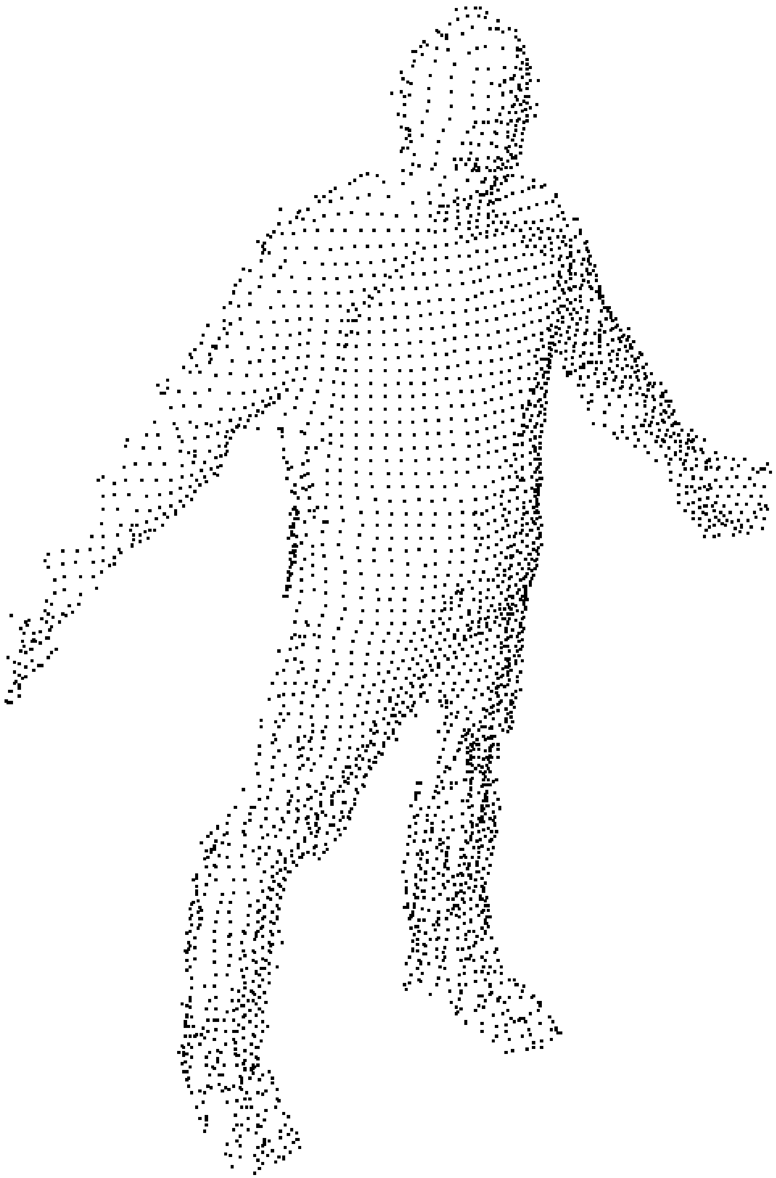
FARO FOCUS 3D

	Día	Semana	15 días	Mes
Láser, trípode y software Scene	250	860	1500	2550
8 Esferas	10	30	50	80

- Clase práctica inicial: 110 € (2 horas)
- Seguro: incremento 4%
- Tarifas válidas durante 2015
- IVA no incluido

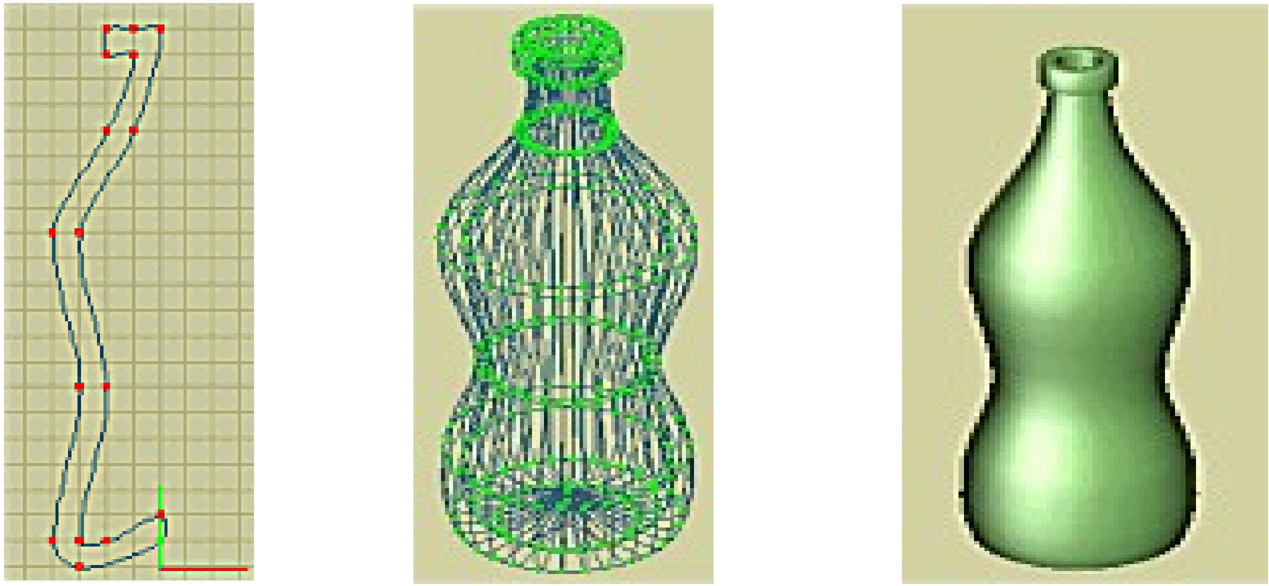
Características:

- 5kg de peso
- Velocidad de 976.000 puntos/s
- Precisión ± 2mm
- Cámara integrada de 70 megapixel



X	Y	Z
1	1	3
4	3	6
7	6	14

	X1	X2	X3	X4
Y1				
Y2				
Y3				



Formas tridimensionales = Interpolación

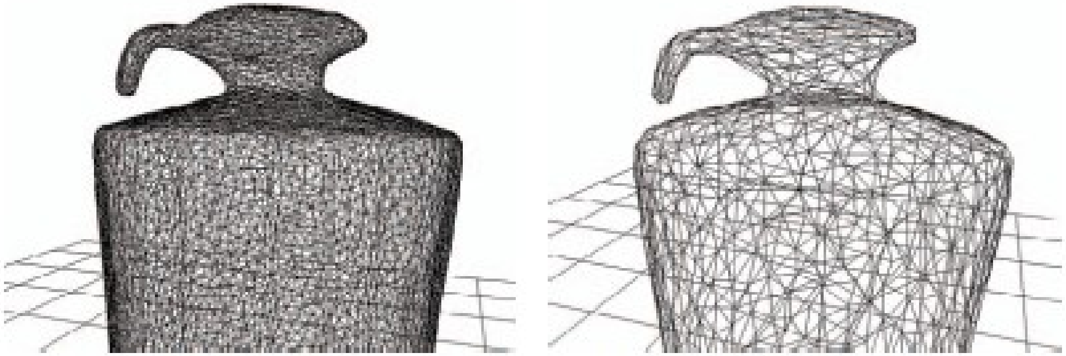


Figura 2.29 Malha poligonal com 10.000 (esq.) e 1.250 (drt.) polígonos [Moitinho07b, c].

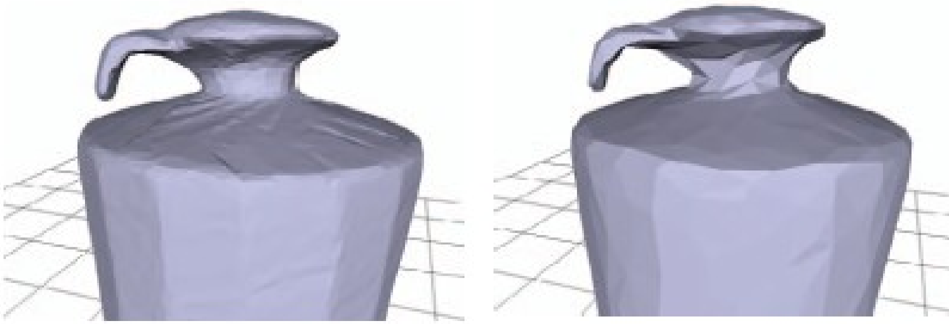


Figura 2.30 *Flat shading* aplicada a malha poligonal com 10.000 (esq.) e 1.250 (drt.) polígonos [Moitinho07b, c].

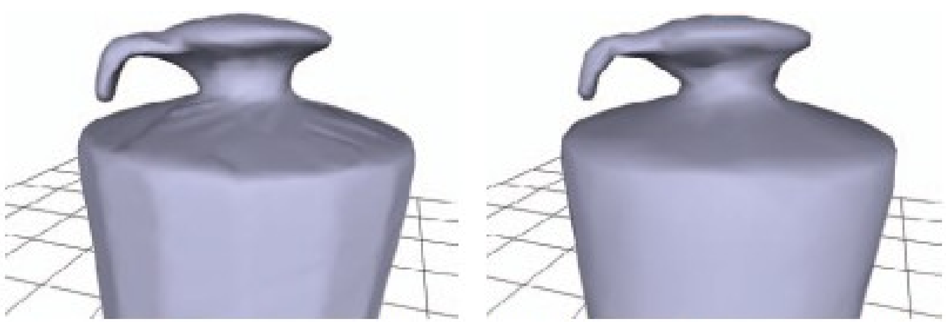
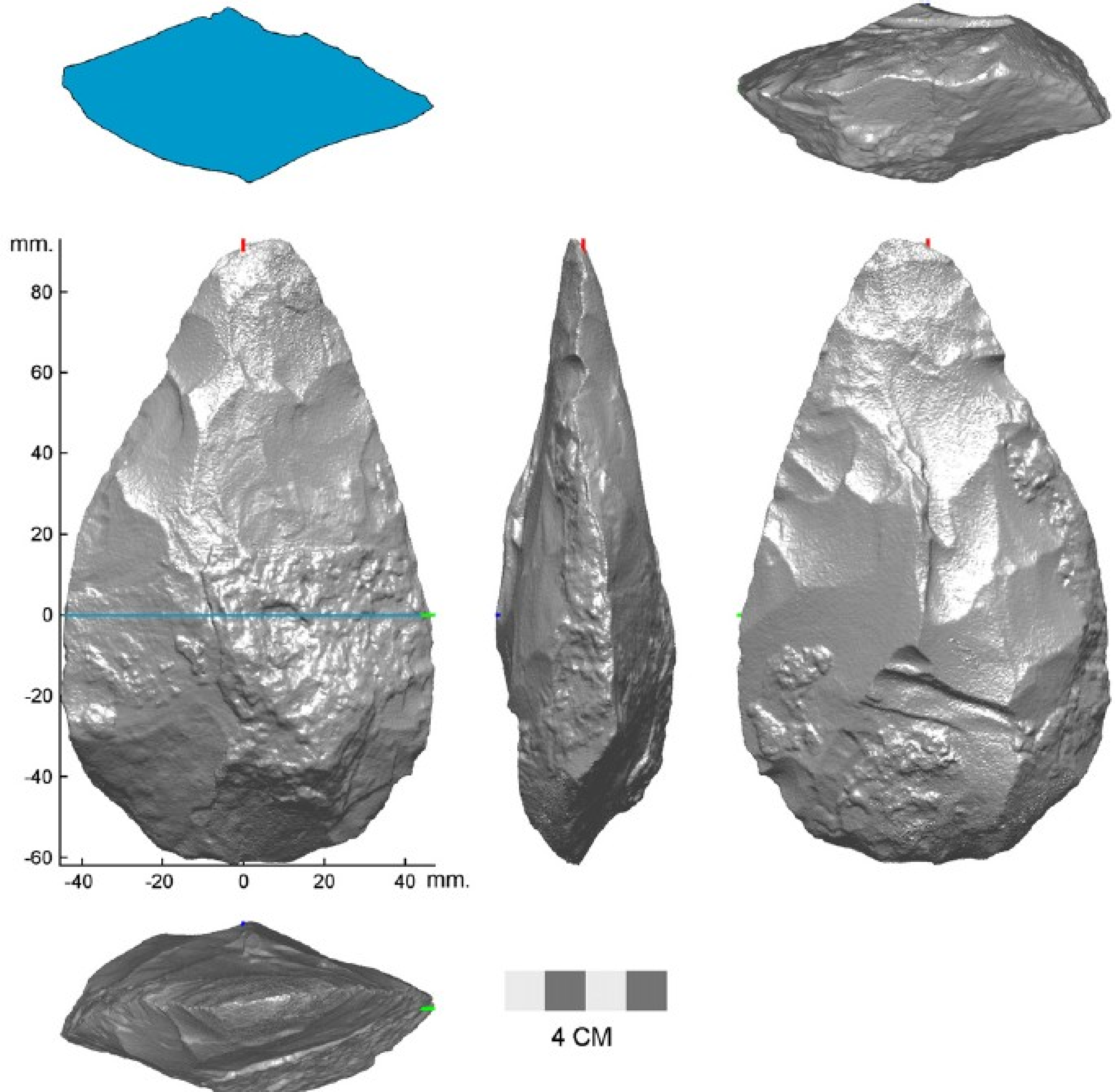


Figura 2.31 *Smooth shading* aplicada a malha poligonal com 10.000 (esq.) e 1.250 (drt.) polígonos [Moitinho07b, c].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mm.
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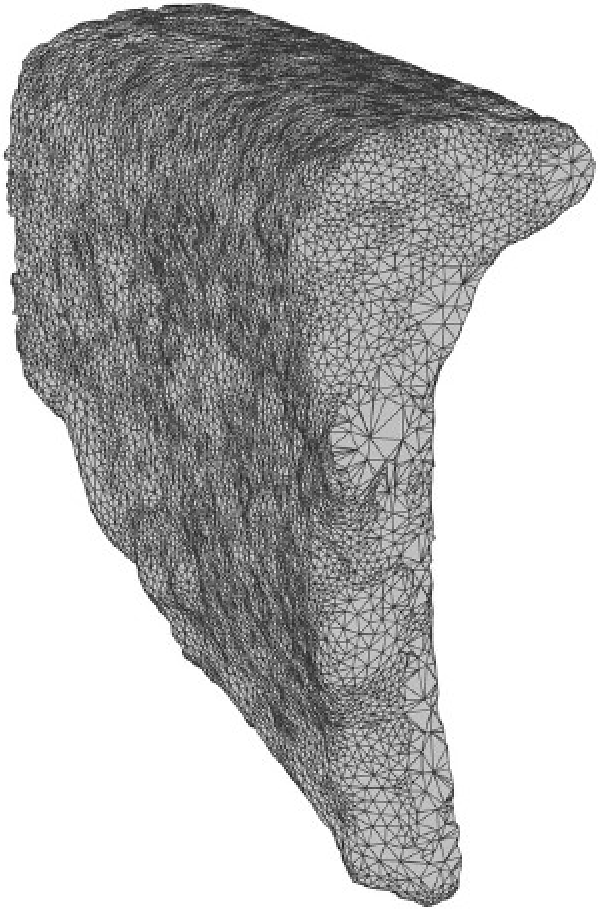
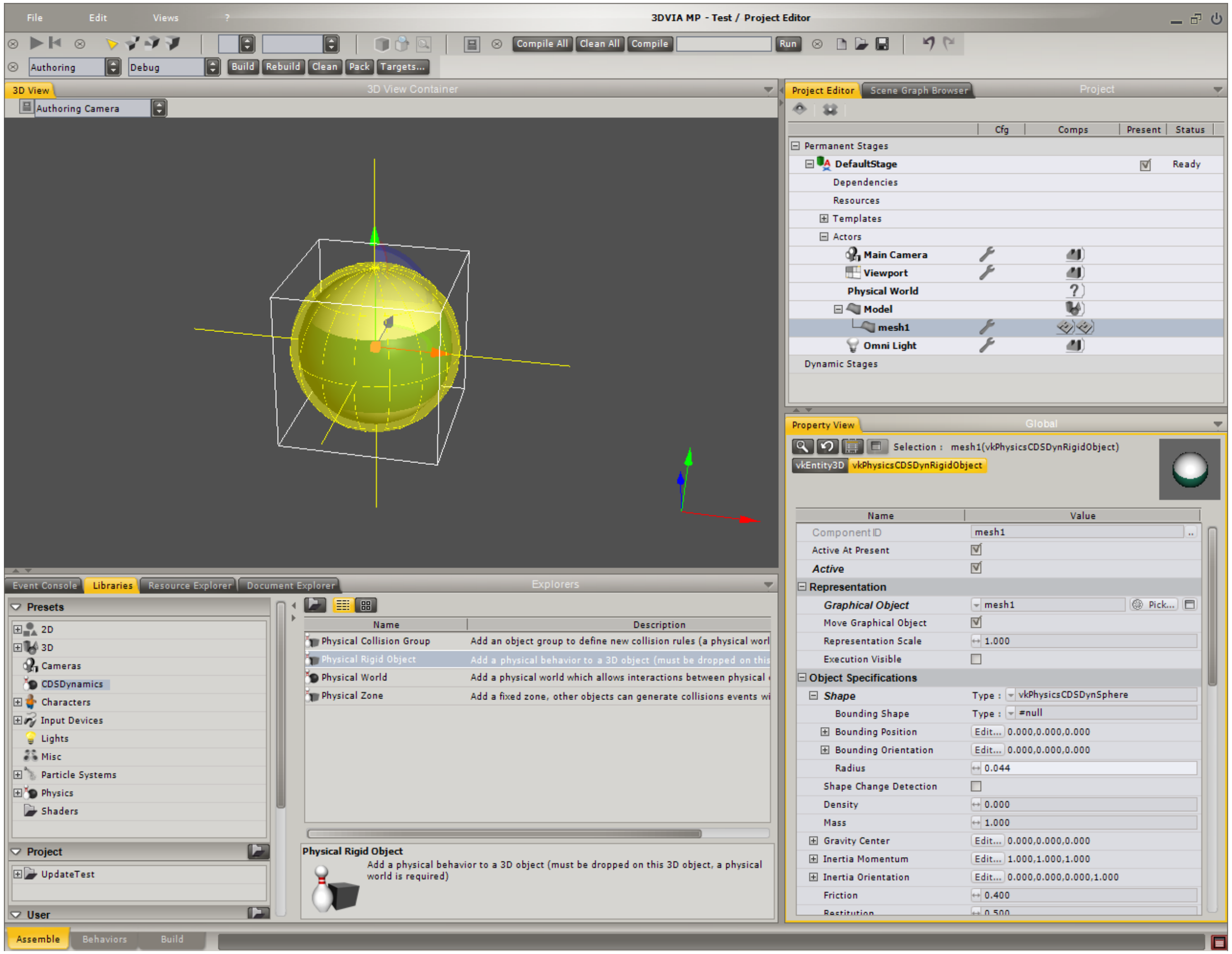
3D File Format

facet normal n_i n_j n_k
outer loop
vertex $v1_x$ $v1_y$ $v1_z$
vertex $v2_x$ $v2_y$ $v2_z$ vertex $v3_x$ $v3_y$ $v3_z$ endloop
endfacet

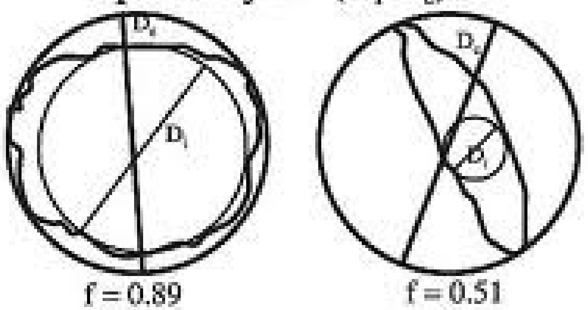


3D Shape Descriptors

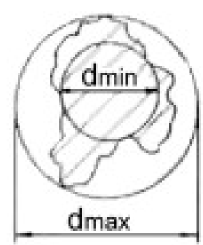


3D Shape Descriptors

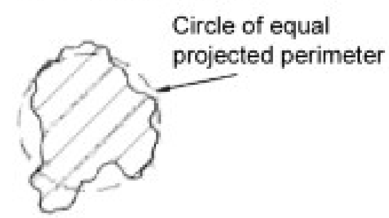
Sphericity $f = (D_i/D_c)^{1/2}$

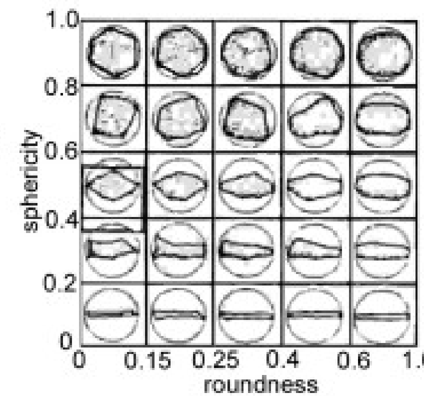


Shape factor

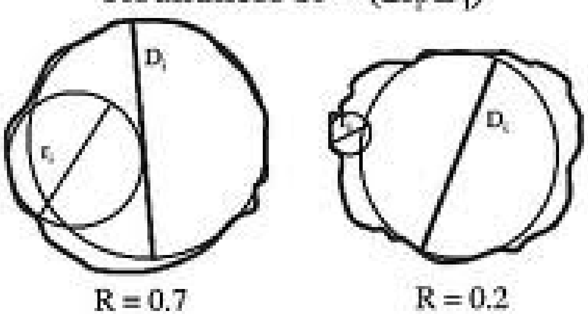


Circularity Factor



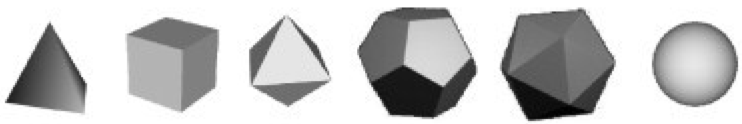


Roundness $R = (2r_i/D_i)$



$$\phi = \frac{\sqrt{a \cdot b^2} \cdot 2^3}{a + \frac{b^2}{\sqrt{a^2 - b^2}} \ln\left(\frac{a + \sqrt{a^2 - b^2}}{b}\right)}$$

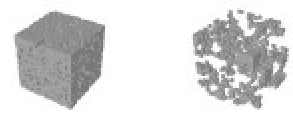
CUBENESS



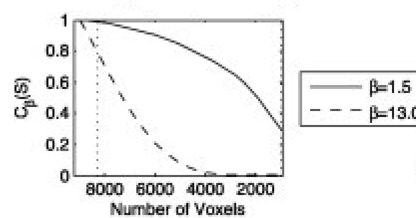
(a) (b) (c) (d) (e) (f)

	$\mathcal{C}_{\beta=0.1}(S)$	$\mathcal{C}_{\beta=1.0}(S)$	$\mathcal{C}_{\beta=5.0}(S)$	$\mathcal{C}_{\beta=10.0}(S)$	$\mathcal{C}_{\beta=30.0}(S)$
(a)	0.9795	0.7923	0.1935	0.0164	0.0000 [3]
(b)	1.0000	1.0000	1.0000	1.0000	1.0000
(c)	0.9974	0.9661	0.7236	0.3753	0.0038
(d)	0.9978	0.9684	0.7155	0.3807	0.0087
(e)	0.9976	0.9691	0.7452	0.4342	0.0247
(f)	0.9979	0.9718	0.7594	0.4489	0.0221

[3]Cubeness measure $\mathcal{C}_{\beta=30.0}(S)$ cannot actually reach zero but the computed value is 0.0000 due to numerical error.



(a) (b)

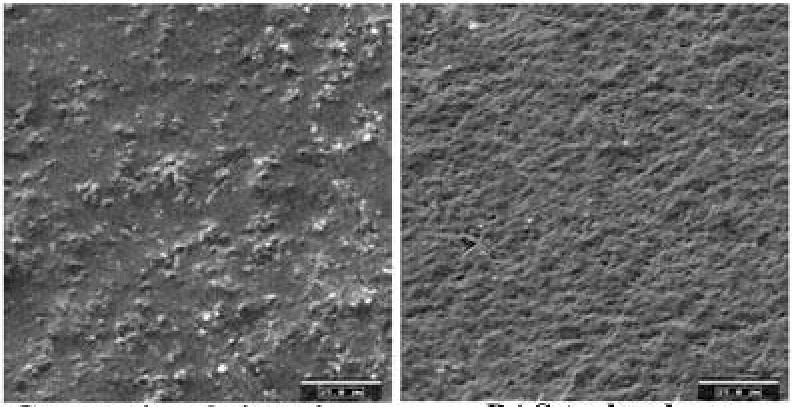


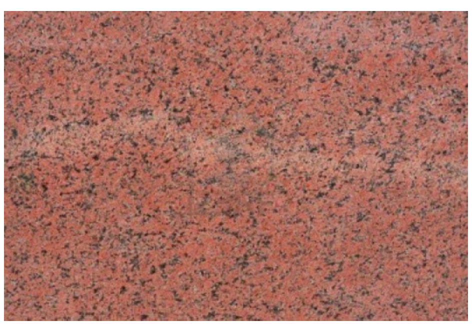
(c)

No. Voxels	% removed	$\mathcal{C}_{\beta=1.5}(S)$	$\mathcal{C}_{\beta=13.0}(S)$
9261	0%	1.000	1.000
8797	5%	0.995	0.935
8333	10%	0.986	0.793
6477	30%	0.922	0.296
3695	60%	0.734	0.012
910	90%	0.287	0.000 [4]

[4]Cubeness measure $\mathcal{C}_{\beta=13.0}(S)$ cannot actually reach zero but the computed value is 0.000 due to numerical error.

Texture





Texture

Definition of those attributes of a surface that have visual or tactile variation and contribute to distinguise those surface from others interacting with it

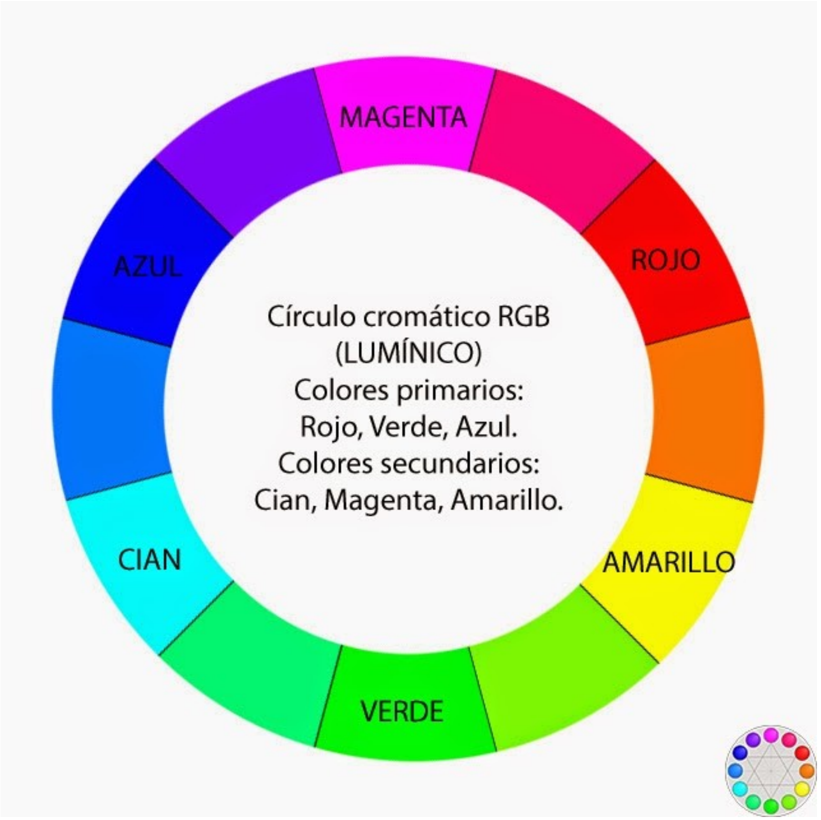
***Any surface shows variation in its properties like:* albedo, color, uniformity, density, roughness, regularity, linearity, direccionality, brightness, defomation, reflectivity, opacity, transparency,**

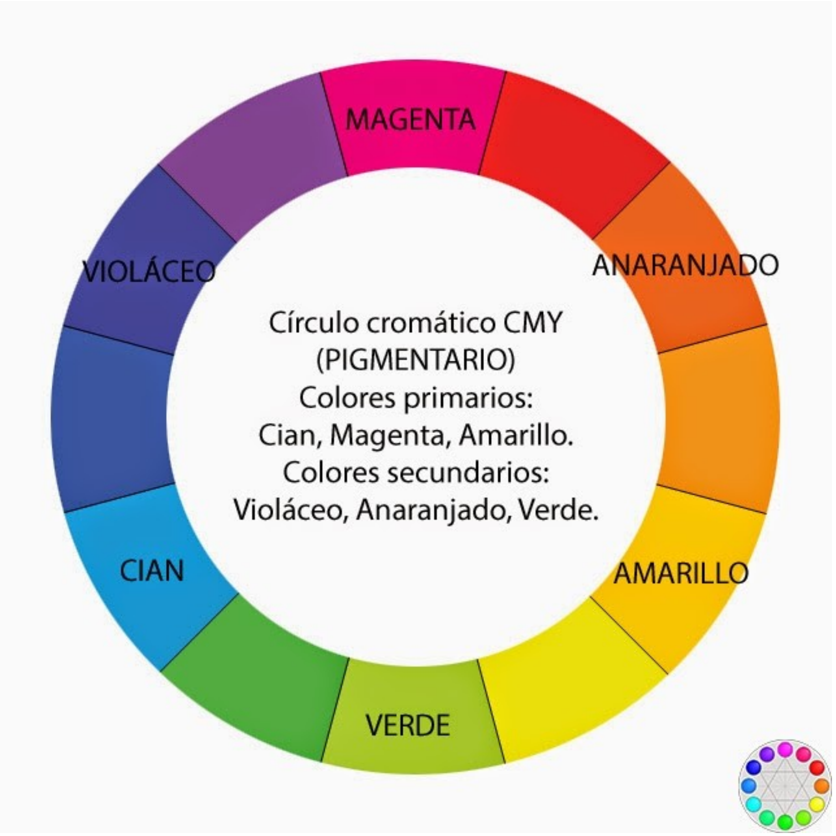
Texture

COLOUR:

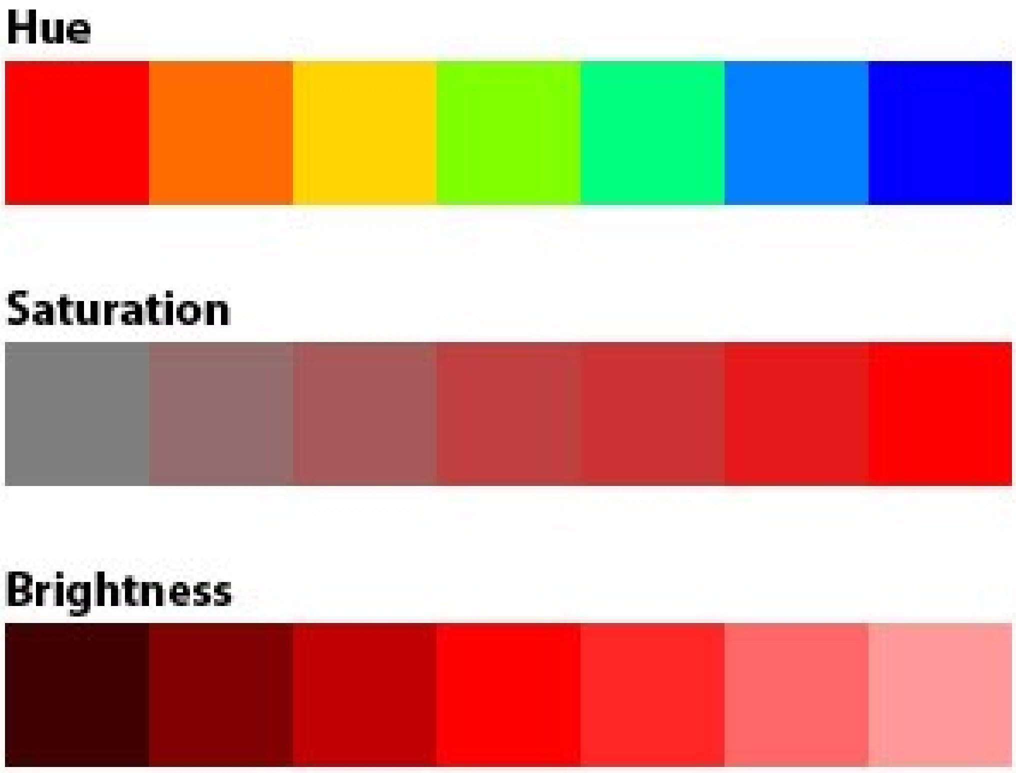
The quality of an object or substance with respect to light reflected by the object, usually determined visually by measurement of hue, saturation, and brightness of the reflected light; saturation or chroma; hue.

Texture

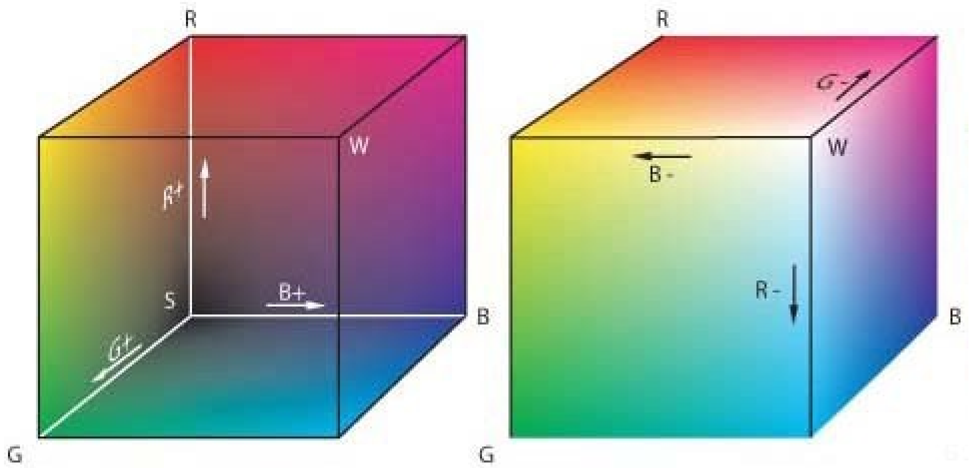

MAGENTA
AZUL
ROJO
Círculo cromático RGB
(LUMÍNICO)
Colores primarios:
Rojo, Verde, Azul.
Colores secundarios:
Cian, Magenta, Amarillo.
CIAN
AMARILLO
VERDE

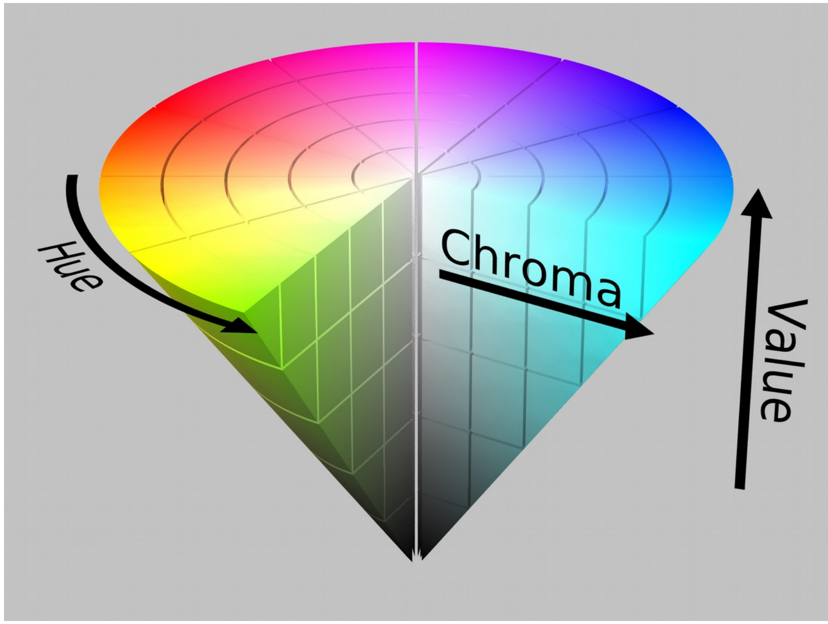

MAGENTA
VIOLÁCEO
ANARANJADO
Círculo cromático CMY
(PIGMENTARIO)
Colores primarios:
Cian, Magenta, Amarillo.
Colores secundarios:
Violáceo, Anaranjado, Verde.
CIAN
AMARILLO
VERDE

Texture



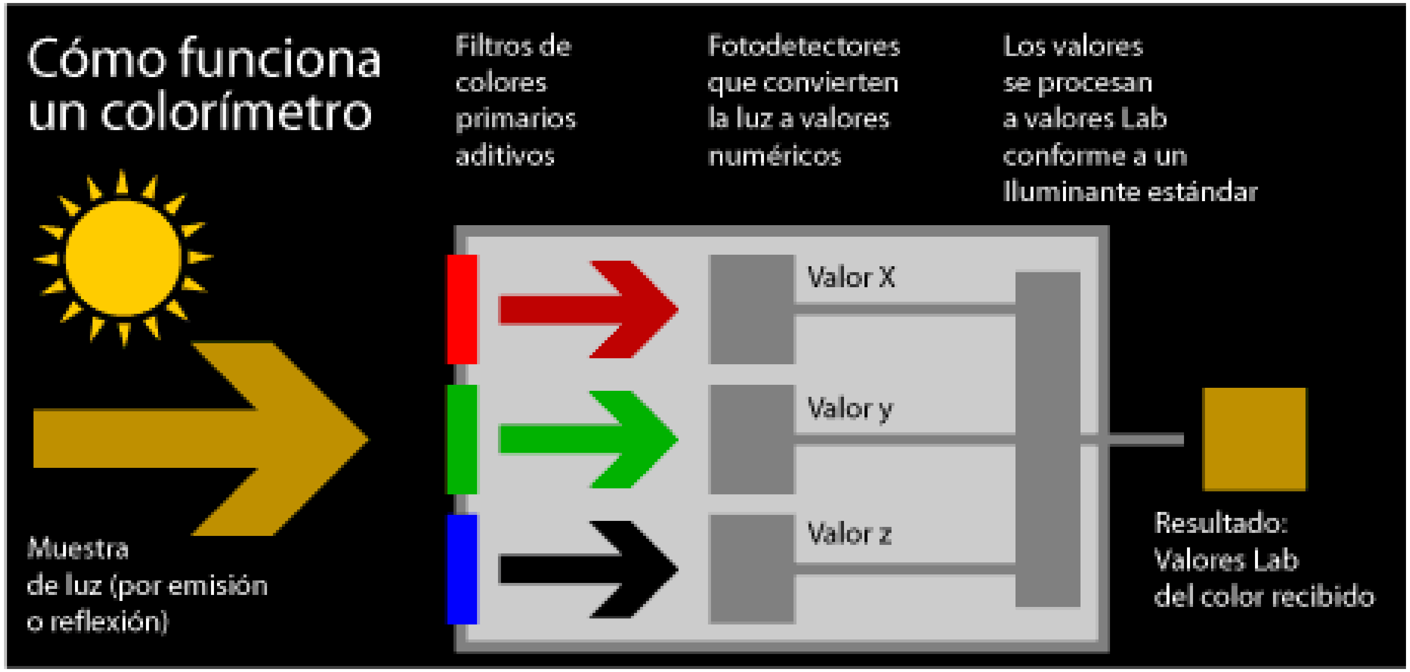
Texture



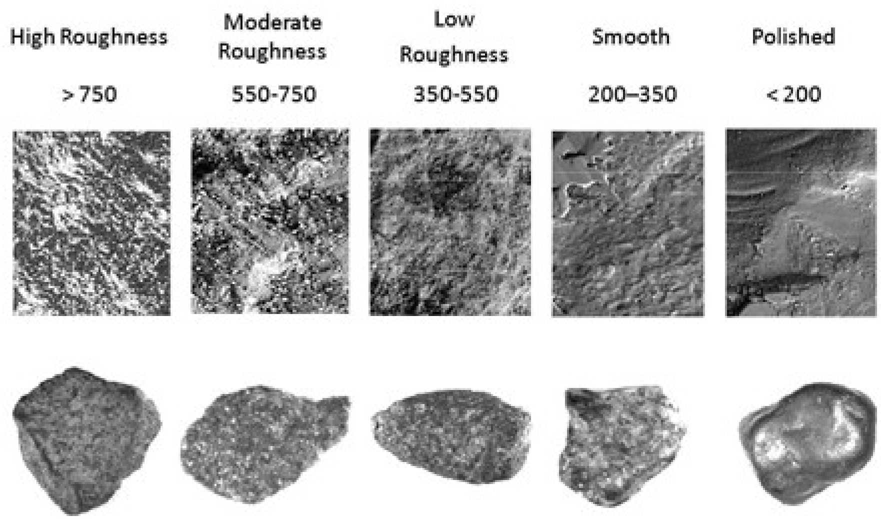


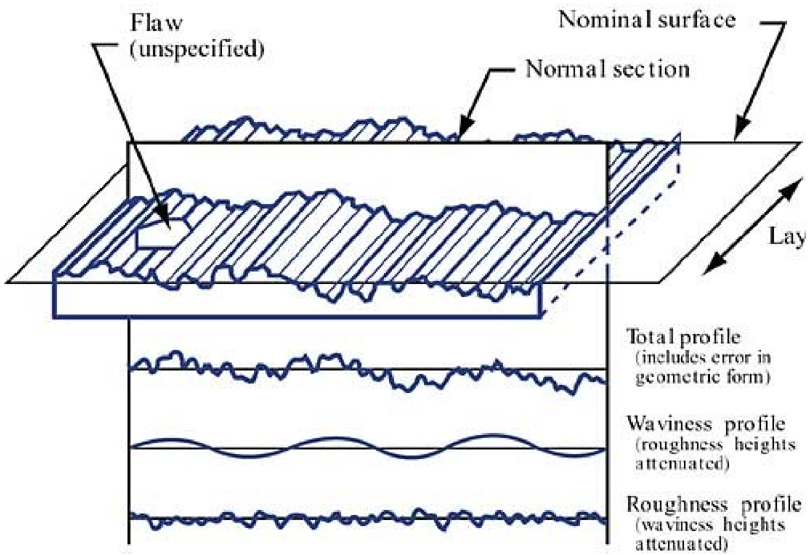
Texture

COLOR: Colorímeter



TACTILE APPEARANCE

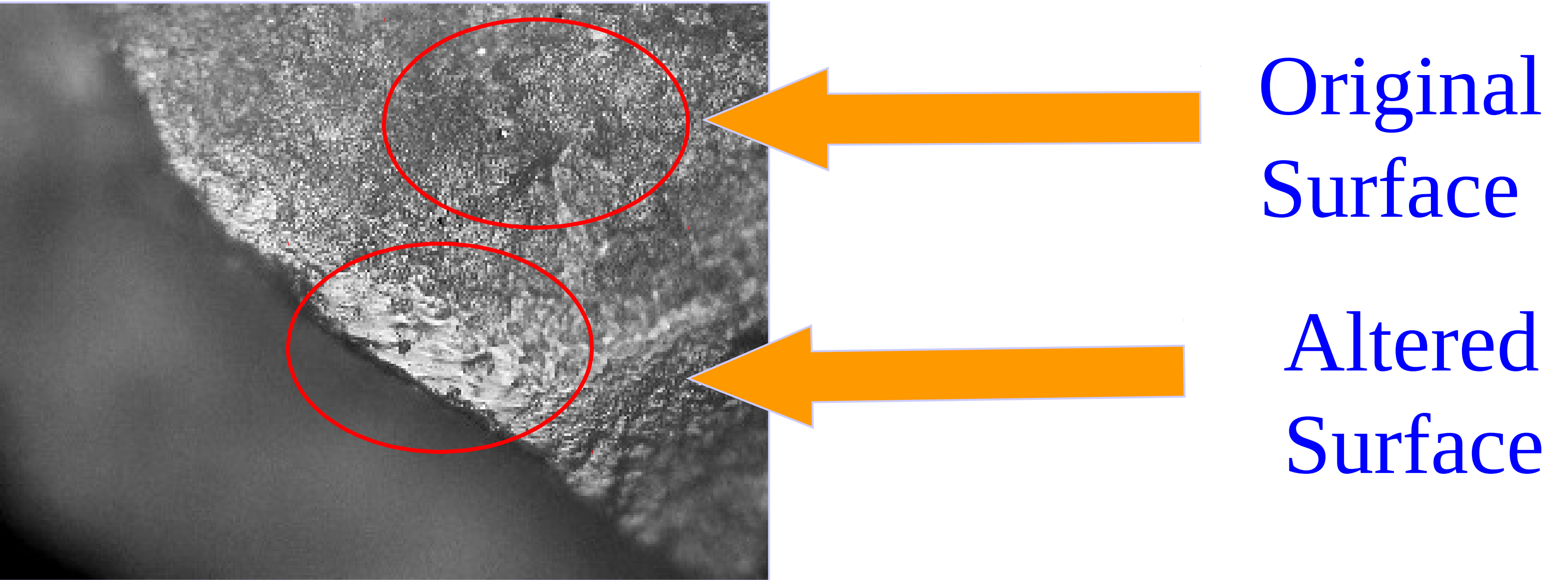


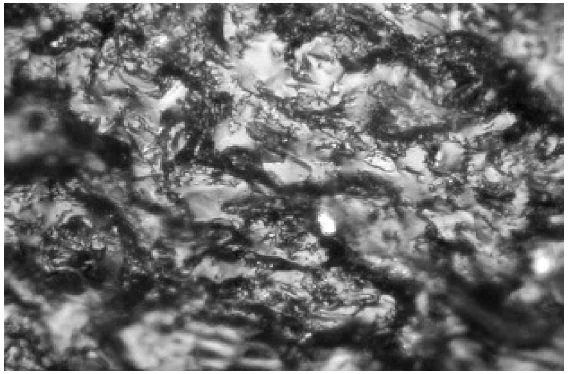
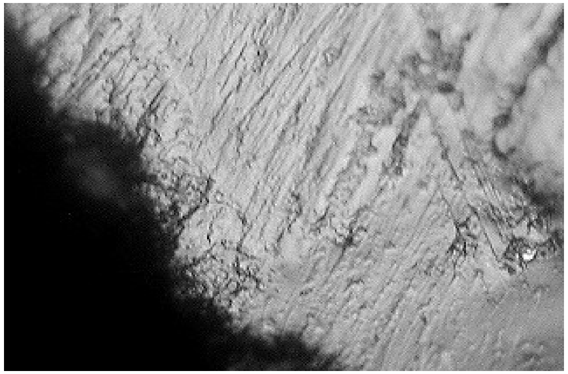
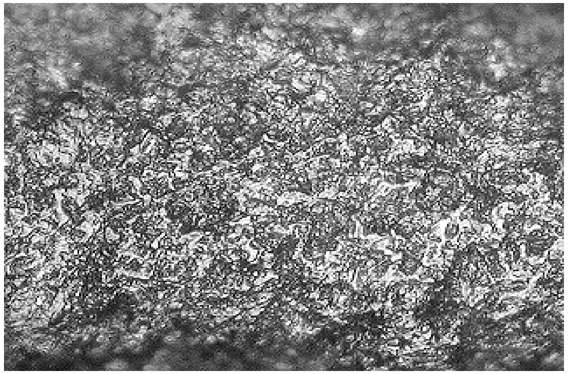
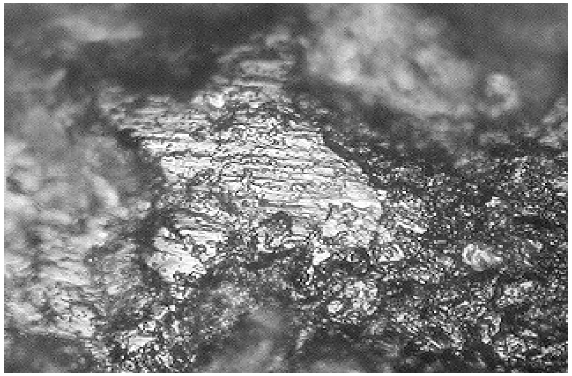
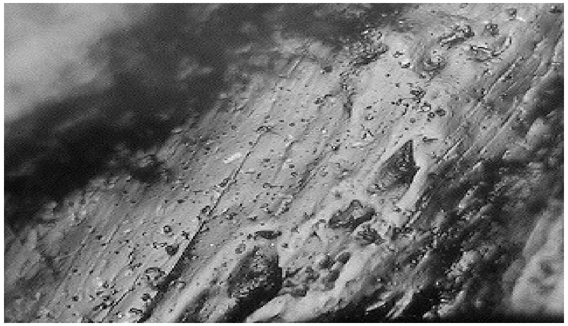
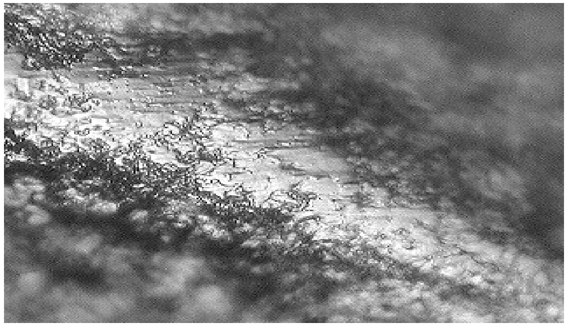


Coarseness,
roughness,
smoothness,
polish,
burnish,
bumpiness,
waviness

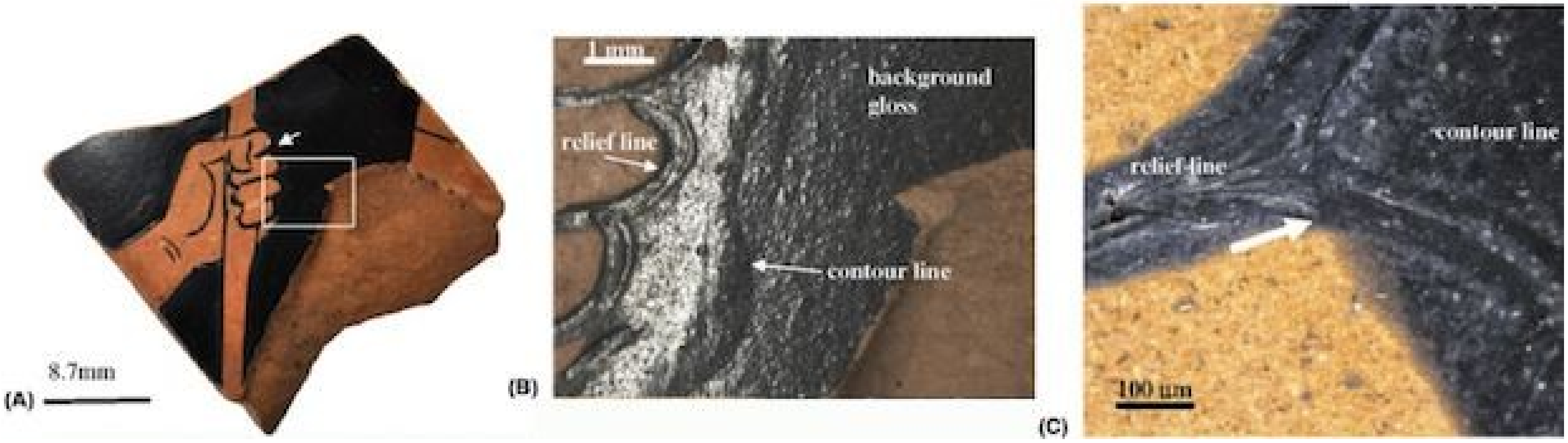
Wear traces as texture

In use wear analysis, we are interested in the nature of the alterations suffered on the lithic tool surface. In this way, our aim is to make inferences about the working processes developed by people that used these tools



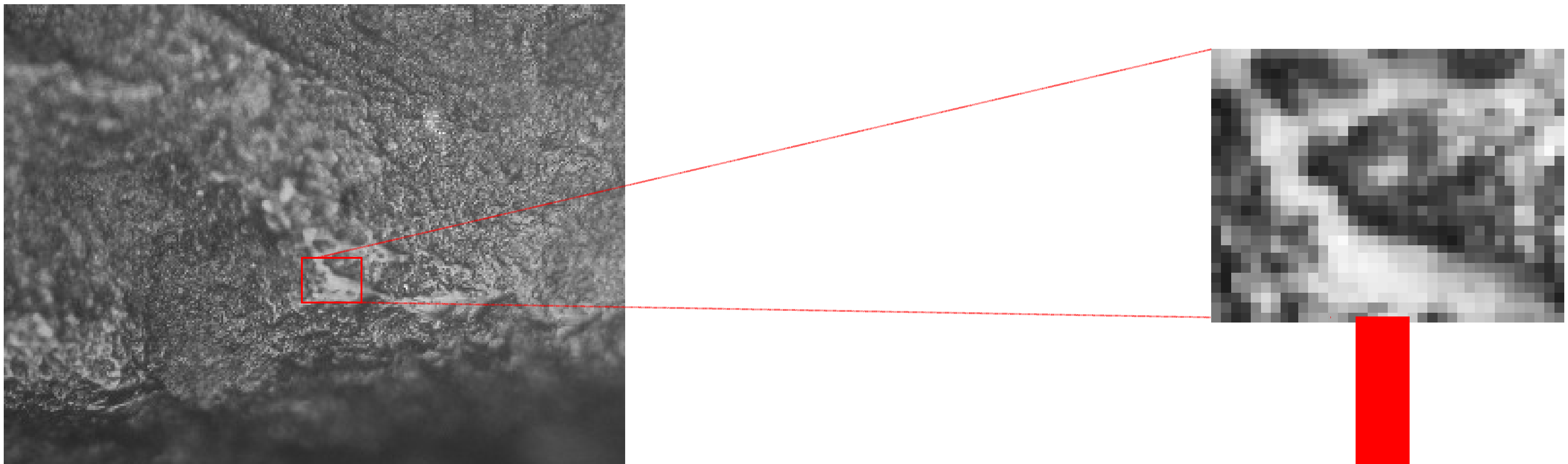







Decoration as Texture



Surface-microtopography:

Coarseness, roughness, smoothness, polish, burnish, bumpiness, waviness



3	3	3	3	3	4	5	6	6	6	6	6	6	6	6	6
3	3	3	3	3	4	4	5	5	6	6	6	6	6	6	6
4	3	3	3	2	4	5	6	6	6	6	6	6	6	6	6
4	3	3	3	4	5	7	8	9	8	7	5	5	5	6	6
3	3	2	3	5	7	8	8	9	8	6	5	5	5	5	5
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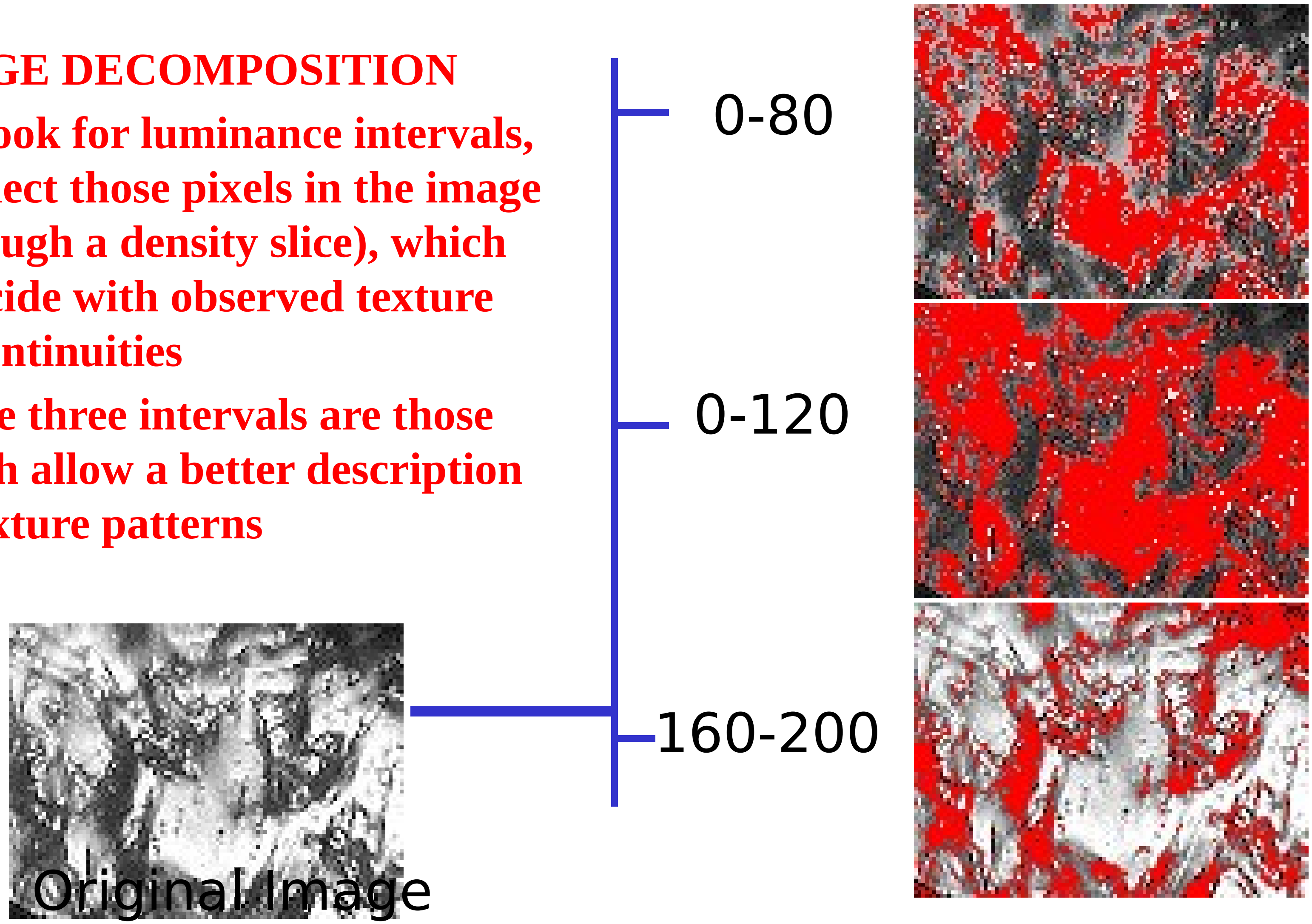
1	1	1	2	2	4	5	6	6	5	5	5	5	5	5	5
2	2	2	3	3	4	4	5	5	5	5	5	5	5	5	5

VISUAL TEXTURE
is a
GEOMETRICAL MODEL OF LUMINANCE
we recognise it as
IMAGES

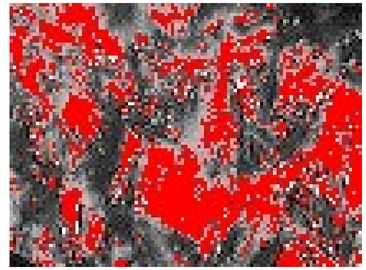
1) IMAGE DECOMPOSITION

- **We look for luminance intervals, to select those pixels in the image (through a density slice), which coincide with observed texture discontinuities**
- **These three intervals are those which allow a better description of texture patterns**

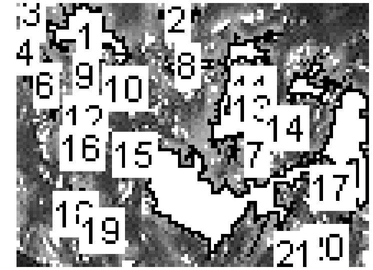
lithics



Original Image



Segmentation



“Texture Components”

Ident	Area	Mean	SD	X	Y	Mode	Length	Major	Minor	Angle	Min	Elongació	Circularitat	Quadratura
1	223	54.74	18.32	21.05	71.22	45	126.75	23.14	13.76	156.83	3	1.68168605	0.17442945	2.12195195
2	44	58.11	16.87	48.68	76.23	59	50.77	10.27	5.46	8.04	21	1.88095238	0.21451083	1.91346637
3	12	48.33	17.64	5.08	77.23	28	16.14	5.61	2.95	143.21	20	1.90169492	0.57887536	1.16480417
4	49	58.06	17.42	2.12	66.72	76	44.28	15.28	4.17	85.97	2	3.66426859	0.31404489	1.58142857
5	234	56.75	17.51	66.05	53.89	68	173.28	34	9.7	73.84	2	3.50515464	0.09793318	2.83191699
6	68	55.19	16.32	8.09	55.81	62	65.5	15.39	5.79	103.91	8	2.65803109	0.19917609	1.98576043
7	1206	46.81	18.43	74.55	29.43	45	513.94	60.43	27.52	24.76	1	2.19585756	0.05737641	3.69980449
8	45	50.8	19.86	52.13	61.66	34	47.94	13.74	4.35	1.53	8	3.15862069	0.24605225	1.78661831
9	10	61.2	17.81	20.62	57.85	80	18.97	5.47	3.02	139.47	21	1.81125828	0.34920159	1.49971018
10	33	50.73	19.65	33.76	54.12	54	45.6	6.76	6.21	13.78	7	1.08856683	0.19943213	1.98448528
11	11	40.45	14.33	71.45	54.36	15	18.14	5.79	2.42	53.26	15	2.39256198	0.42007709	1.36735395
12	115	57.24	16.81	21.33	46.22	56	74.57	13.76	11.1	104.19	6	1.23963964	0.25988453	1.73842209
13	15	45.67	21.89	72.24	49.06	11	22.63	6.23	3.48	82.3	11	1.79022989	0.36807221	1.46076022
14	11	43.09	17.32	81.91	42.36	54	13.31	4.35	3.22	70.01	13	1.35093168	0.78027457	1.003279
15	47	45.91	17.24	36.04	35.02	61	51.6	12.61	4.85	71.07	7	2.6	0.22182441	1.88165839
16	12	49.58	21.56	19.58	36.33	47	20.97	5.44	2.81	133.25	5	1.93594306	0.34292193	1.51337939
17	29	48.31	19.19	96.3	23.7	27	37.7	9.96	3.83	121.04	18	2.60052219	0.25640482	1.75017856
18	58	45.93	23.26	18.22	18.14	75	49.7	14.83	4.98	94.56	1	2.97791165	0.29507071	1.63148243
19	36	59.39	16.54	25.2	10.93	58	30.38	10.87	4.68	78.57	8	2.32264957	0.49015997	1.26583333
20	32	41.91	27.31	93.42	4.97	75	46.43	12.57	3.34	138.17	1	3.76347305	0.18653636	2.05193549
21	39	40.87	16.81	85.1	3.56	30	33.46	8.09	6.14	49	8	1.31758958	0.43774744	1.33947201

DESCRIBING TEXTURE

The features that we take in account are:

By Shape:

- Elongation
- Circularity
- Quadrature
- Thinness
- Ratio Compactnes/Thinness
- Compactness, mesured through two equations
- Irregularity
- Rectangularity, mesured through two equations
- Ratio Perimeter/Elongation
- Feret diameter
- Minimum rectangularity

By Composition:

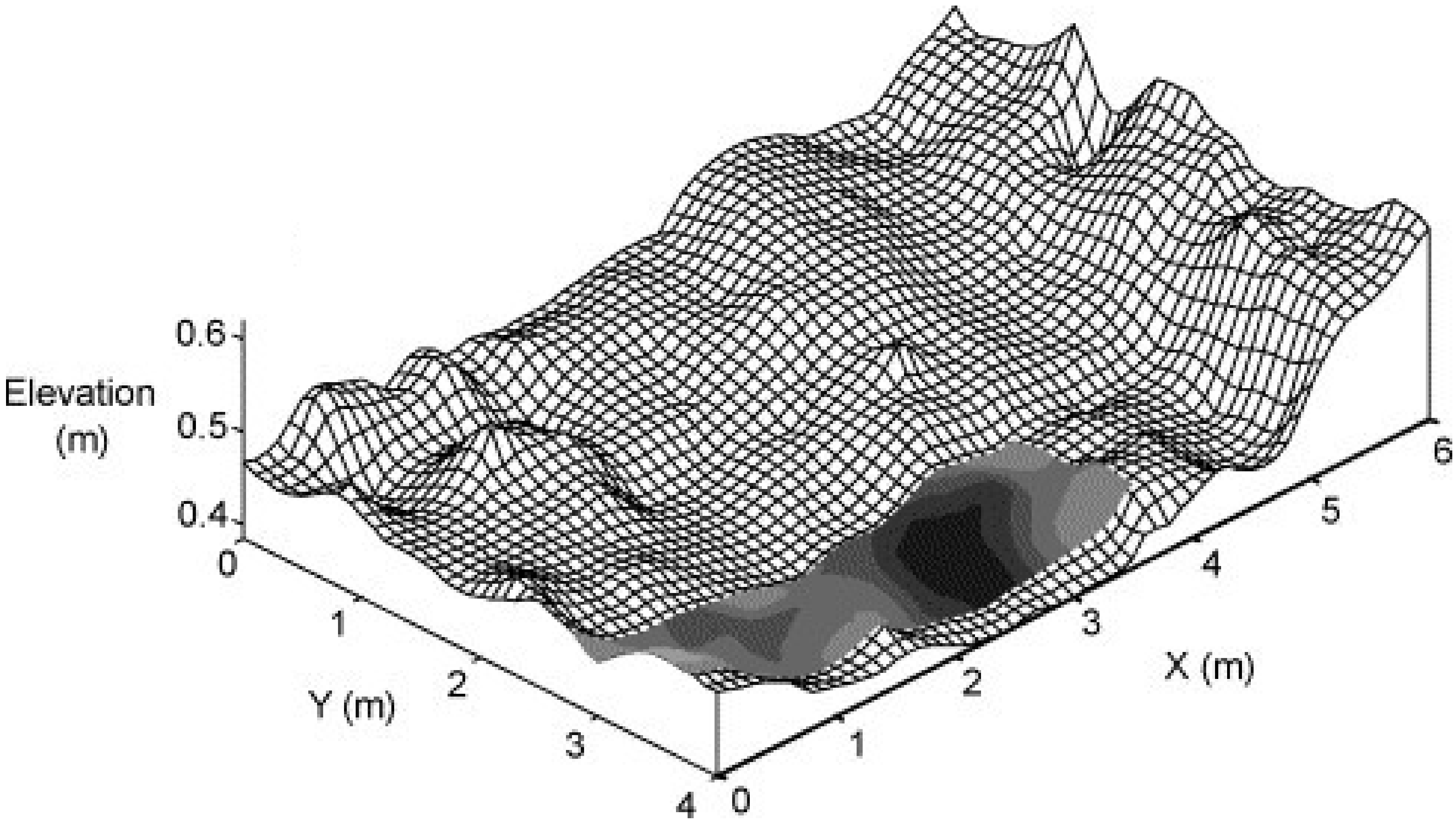
- Mean, mean of luminance
- SD, standard deviation of luminance
- Mode, mode of luminance
- Min, minimum luminance value

By Size:

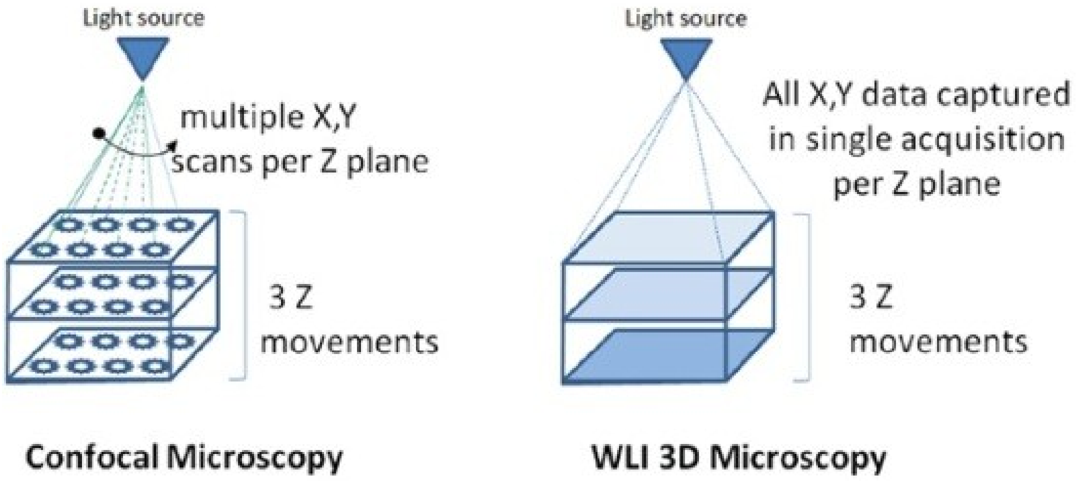
-Area
-Major axis
-Major axis perpendicular to the major axis
-Perimeter

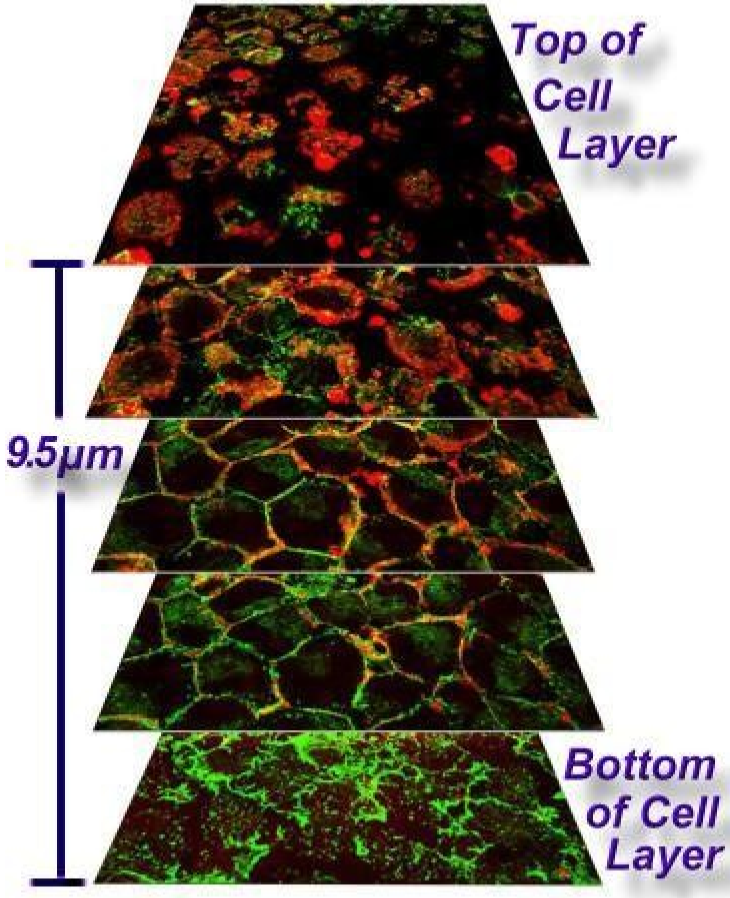
Surface-microtopography:

Coarseness, roughness, smoothness, polish, burnish, bumpiness, waviness

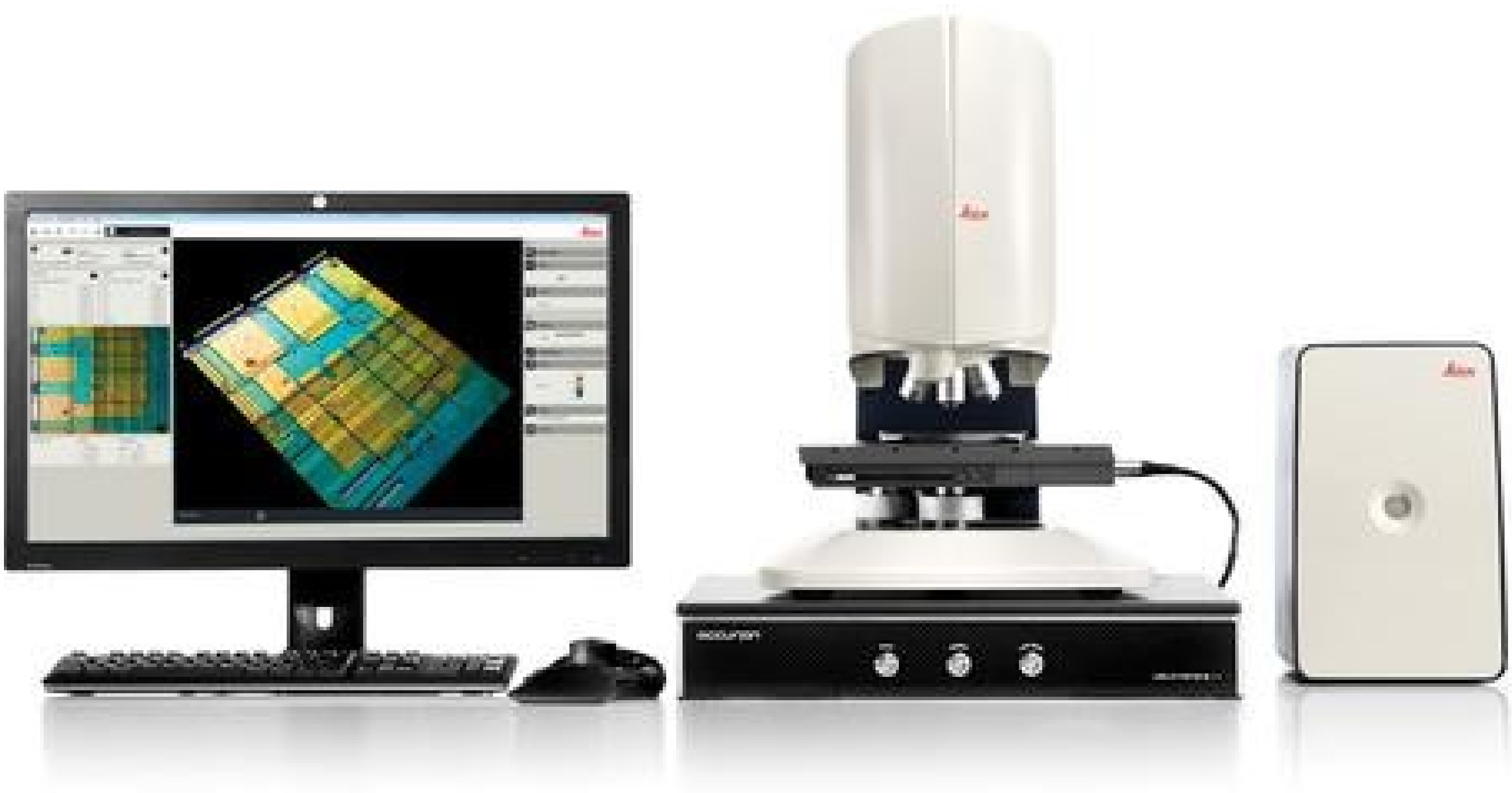


CON-FOCAL MICROSCOPY AT DIFFERENT SCALES



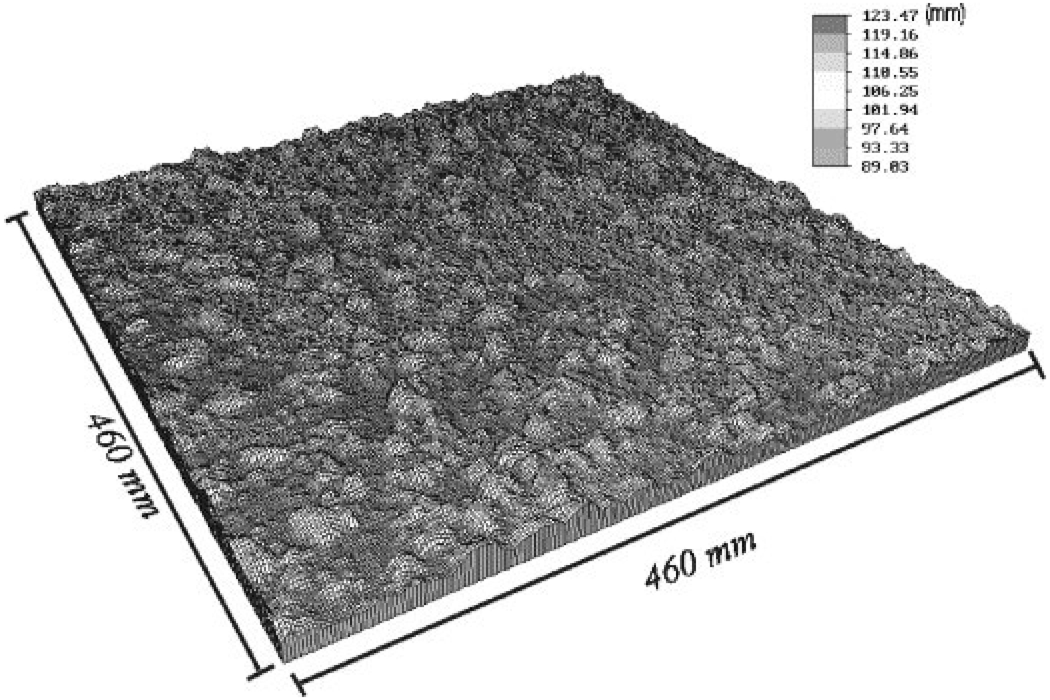


Leica DCM8 METROLOGY MICROSCOPE OF 3d SURFACES de superficies 3D combining confocal microscopy and interferometry



Surface-microtopography:

Coarseness, roughness, smoothness, polish, burnish, bumpiness, waviness

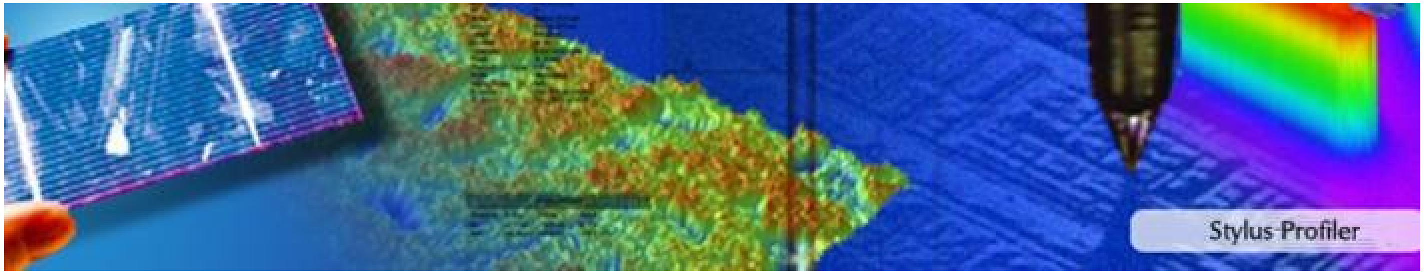


A modern range scanner captures surface data points less than 50 microns (0,05 mm), apart from producing high-density triangular meshes with an average resolution of over 1000 points per cm^2.

Surface-microtopography:

Coarseness, roughness, smoothness, polish, burnish, bumpiness, waviness

Mechanical profilometer:
Nanometric resolution



Surface-microtopography:

Coarseness, roughness, smoothness, polish, burnish, bumpiness, waviness

Profilometer

Resolution: µm / 0,006 µm100 µm / 0,002 µm25 µm / 0,0004 µm

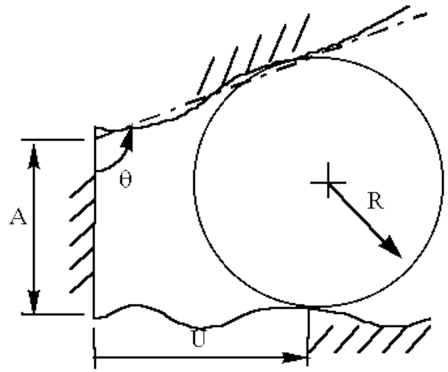
Surface-microtopography:

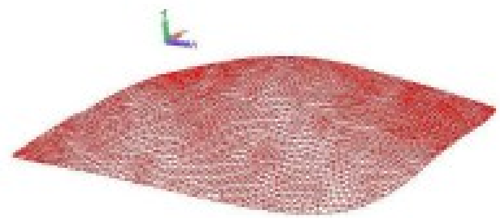
Coarseness, roughness, smoothness, polish, burnish, bumpiness, waviness

Alta precisión en el tipo 1.7µm
Crysta Apex S es una MMC CNC que garantiza un error máximo admisible de medición MPEE = (1.7 + 3 L/1000) µm [Serie 500/700/900].
Sistema de Compensación de Temperatura

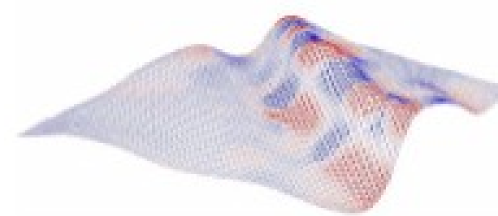
Surface-microtopography:

Coarseness, roughness, smoothness, polish, burnish, bumpiness, waviness





CVM = 0.022

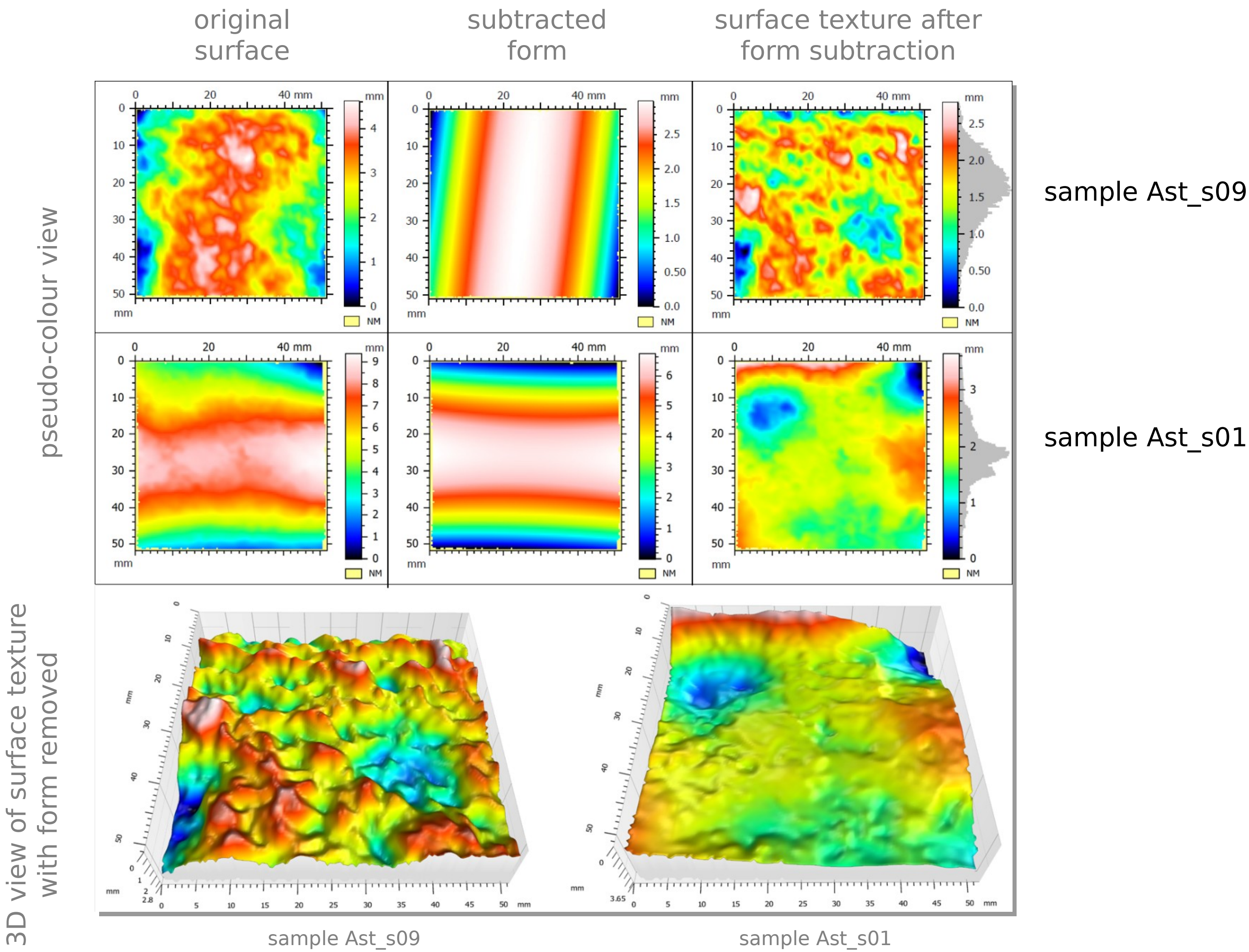


CVM = 0.43

Waviness measurement

Gaussian Curvature

3D Digital surface texture patterns description



ISO 25178 series

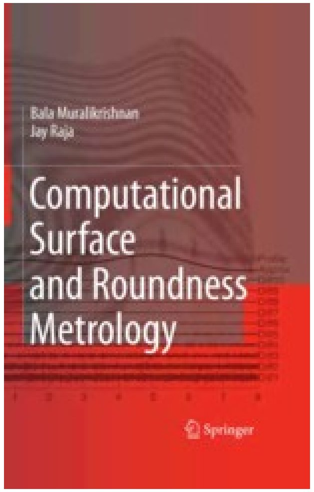
ISO (2012). *ISO 25178-2:2012 - Geometrical Product Specifications (GPS) - Surface texture: Areal - Part 2: Terms, definitions and surface texture parameters*. International Standard Organization (ISO).

The ISO 25178 series define more than 40 areal parameters, grouped in:

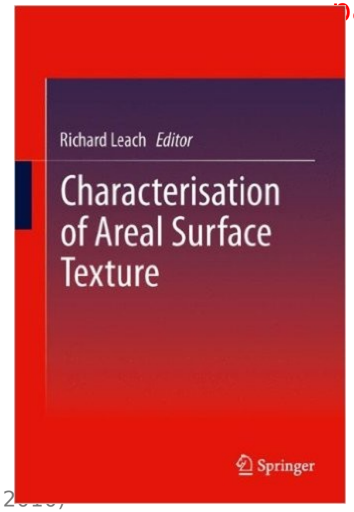
- Height: statistical distribution of height values along the z axis.
- Spatial: spatial periodicity of the data, specifically its direction.
- Hybrid: spatial form of the data, i.e., amplitude and spatial information.
- Functional volume: surface bearing area ratio curve (Abbott- Firestone curve).
- Features: selected features are identified by segmentation.

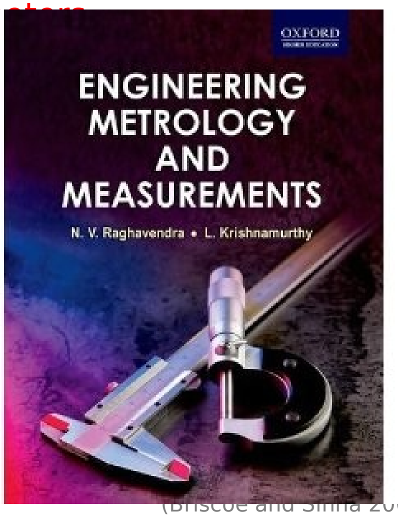
Calculations are made upon the entire surface

AND NOT upon averaging estimation calculations derived from 2D profilometric methods and parameters

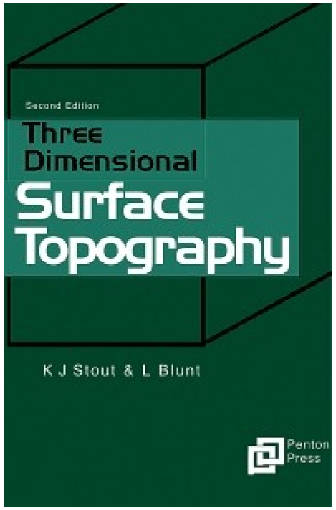


(ASME 2010)





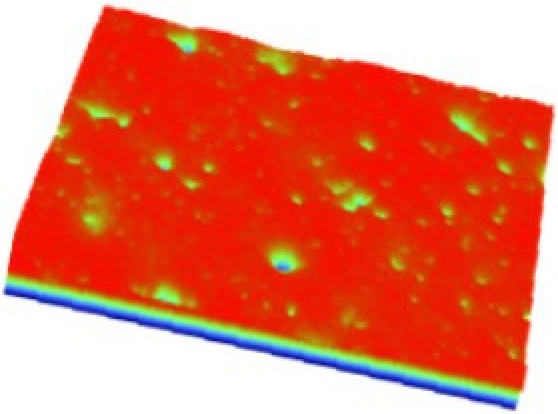
(Briscoe and Sinha 2002)



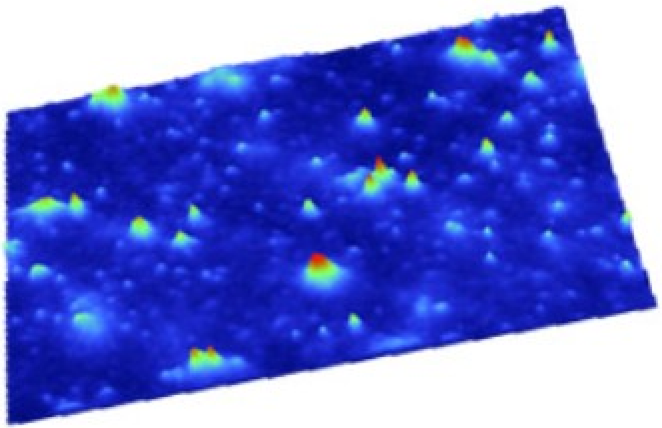
Sa and Sq

Sa and **Sq** are the Average Roughness and Root Mean Square Roughness are evaluated over the complete 3D surface respectively. Mathematically, **Sa** and **Sq** are evaluated as follows:

$$S_a = \iint_a \left|Z(x,y)\right| dxdy \qquad Sq = \sqrt{\iint_a (Z(x,y))^2 dxdy}$$



Plateau-like surface Sa = 16.03 nm Sq= 25.4 nm

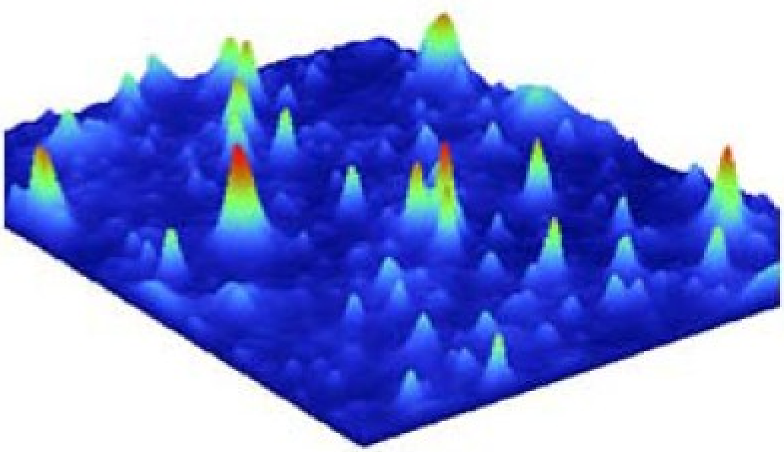


Surface with Peaks Sa = 16.03 nm Sq= 25.4 nm

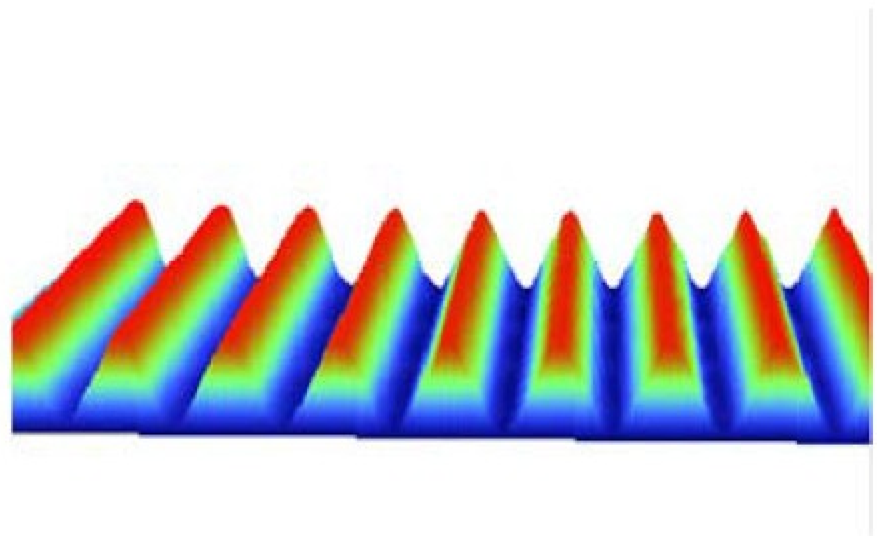
Ssk (Skewness) and Sku (Kurtosis)

Ssk and **Sku** are the Skewness and *Kurtosis of the 3D surface texture respectively. Figuratively, a histogram of the heights of all measured points is established and the symmetry and deviation from an ideal Normal (i.e. bell curve) distribution is represented by* ***Ssk*** *and* ***Sku****. Mathematically, the* ***Ssk*** *and* ***Sku*** *are evaluated as follows:*

$$Ssk = \frac{1}{S_q^3} \iint_a (Z(x,y))^3 dxdy \qquad S_{ku} = \frac{1}{S_q^4} \iint_a (Z(x,y))^4 dxdy$$



Surface with multiple peaks Ssk = 3.20 Sku = 18.71

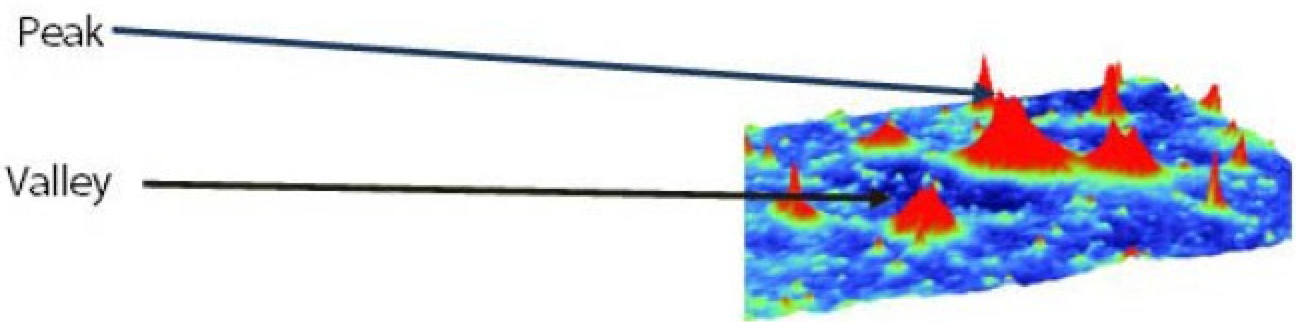


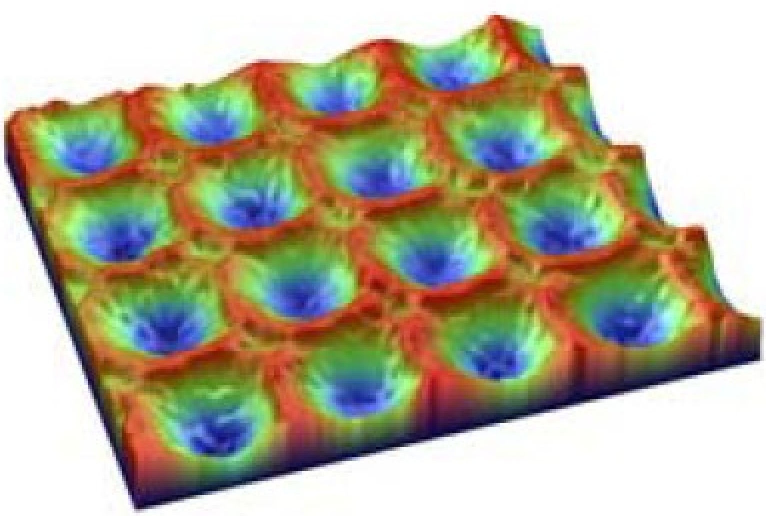
Periodic Texture Ssk = 0.16 Sku= 1.63

Sp (Max Peak Height), Sv Max Valley Depth) and Sz (Max Height of Surface)

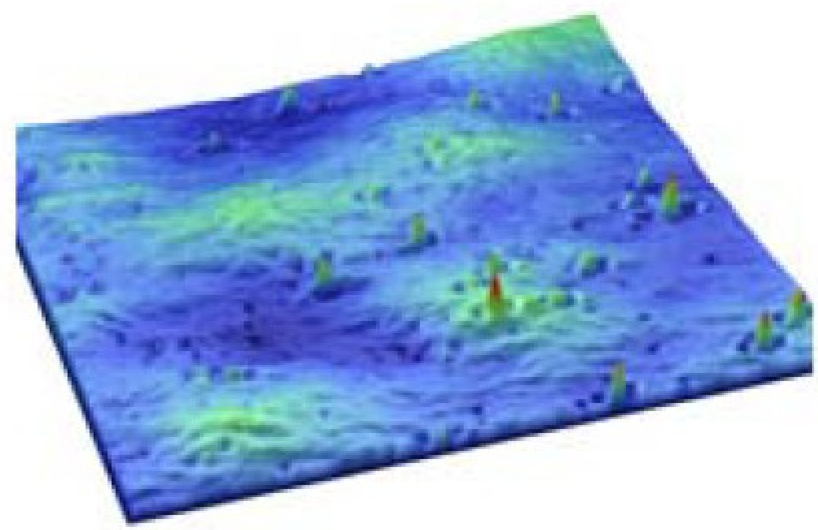
Sp, ***Sv***, *and* ***Sz*** *are parameters evaluated from the absolute highest and lowest points found on the surface.* ***Sp,*** *the Maximum Peak Height***,** *is the height of the highest point,* ***Sv***, *the Maximum Valley Depth, is the depth of the lowest point (expressed as a negative number) and* ***Sz*** *the Maximum Height of the Surface), is found from* ***Sz = Sp – Sv***.

Note: ***earlier standards*** *referred to* ***Rz*** *as a average of the 10 highest to 10 Lowest Points and other variations. The ISO community agreed for the newer standard, ISO 25178-2 to establish Sz as strictly the peak to valley height over a areal measurement.*





A surface used in the printing industry characterized by deep valley structures with Sv being ~ -15µm

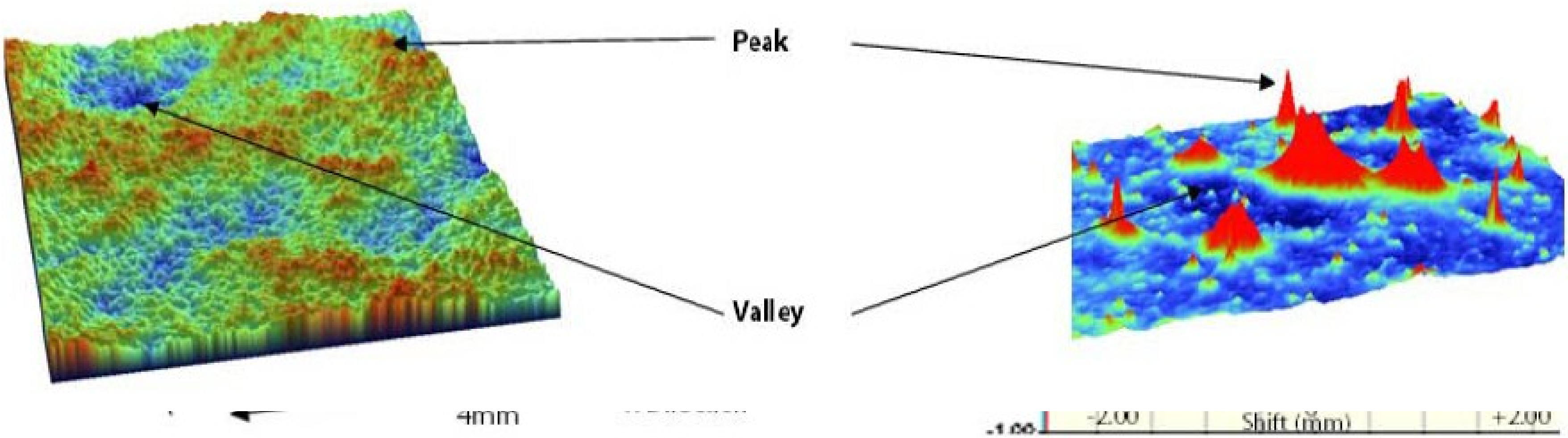


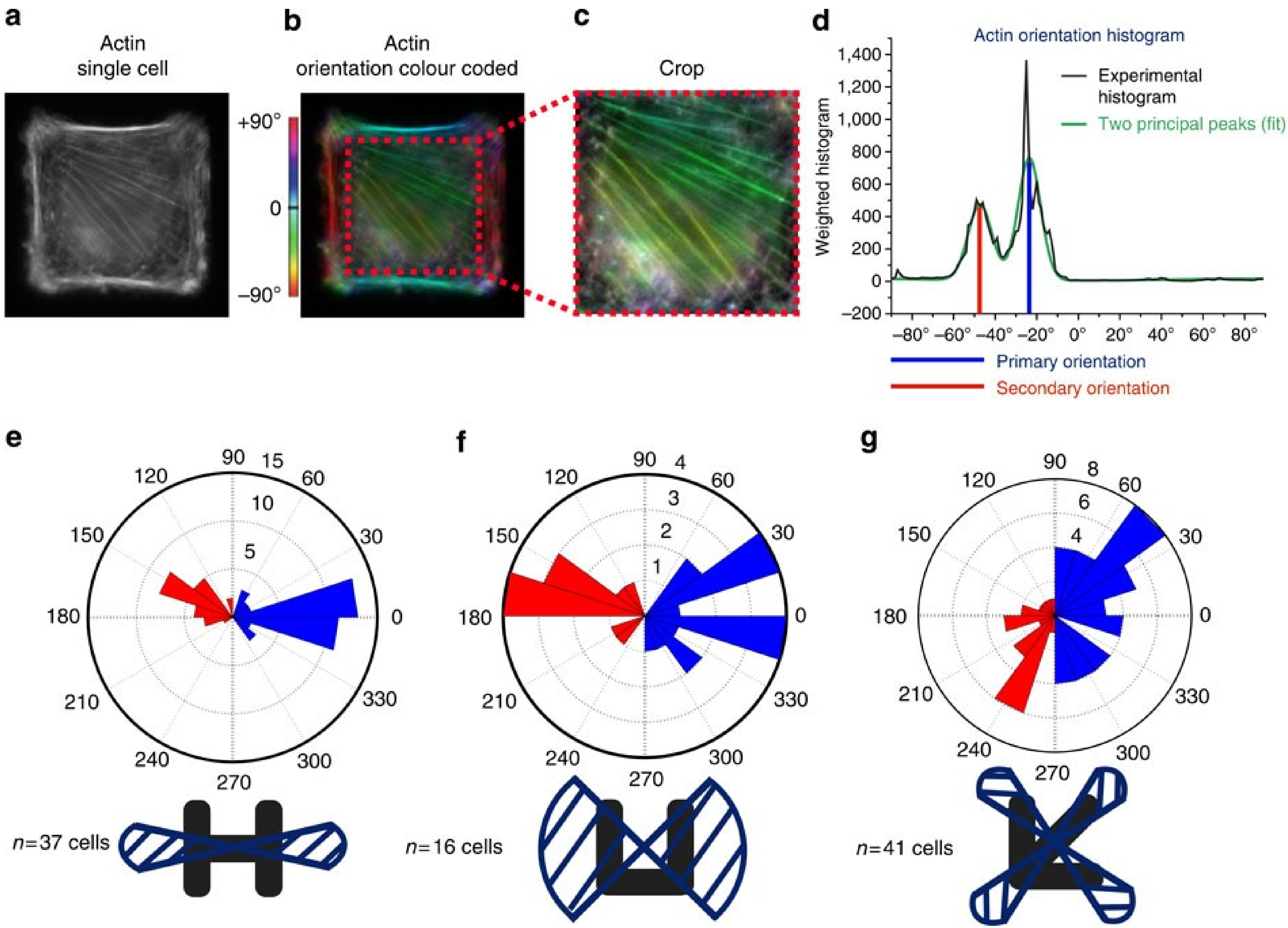
A polymer surface prepared with asperities as measured by Sp being ~0.90 µm

ACF (Autocorrelation Function)

Rpm, Rvm and Rz (Average Max Peak Height, Valley Depth and Height of Surface)

The **Rpm**, **Rvm**, and **Rz** parameters are evaluated from an average of the heights and depths of a number of extreme peaks and valleys. **Rpm** the Average Maximum Peak Height, is found by averaging the heights of the ten (10) highest peaks found over the complete 3D image. **Rvm,** the Average Maximum Valley Depth, is found by averaging the depths of the ten (10) lowest valleys found over the complete 3D image. **Rz,** the Average Maximum Height of the Surface, is found from **Rpm**-**Rvm**. Note that in determining the peaks and valleys, the analysis software eliminates a grid of 11 x 11 pixels around a given peak/valley before searching for the next peak/valley, thus assuring that significantly separated peaks/valleys are found.





a
Actin
single cell
b
Actin
orientation colour coded
+90°
0
−90°
c
Crop
d
Actin orientation histogram
Experimental histogram
Two principal peaks (fit)
Weighted histogram
1,400
1,200
1,000
800
600
400
200
0
−200
−80° −60° −40° −20° 0° 20° 40° 60° 80°
Primary orientation
Secondary orientation
e
90 15 60 120 10 150 5 30 180 0 210 330 240 300 270
n=37 cells
f
90 4 60 120 3 150 2 30 1 180 0 210 330 240 300 270
n=16 cells
g
90 8 60 120 6 150 4 30 180 0 210 330 240 300 270
n=41 cells

SURFACE METROLOGY

http://www.michmet.com/index.html

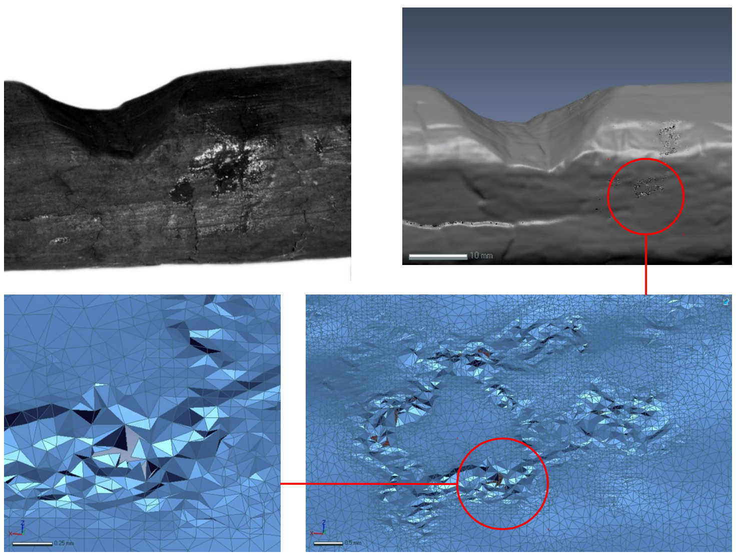
Free Software: http://digitalmetrology.com/free-software/

The freeware version of **SigmaSurf** allows users to import data (through an ASCII file format) and study the effects of various filters while viewing the Primary, Waviness and Roughness profiles at various scales.

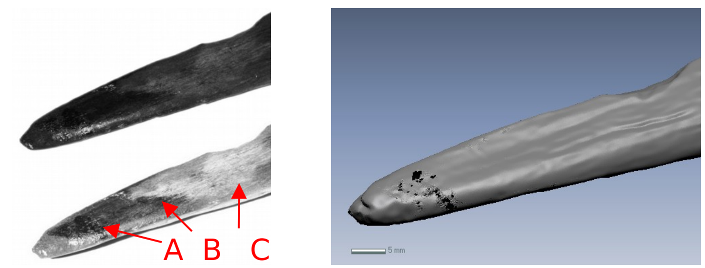
Using a 3D scan for measuring surface-microstructure. Neolithic wood tools

Some difficulties during 3D data

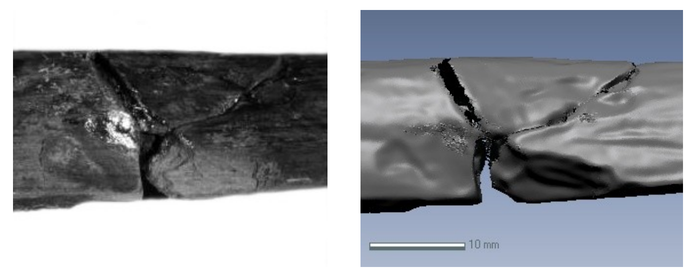
capture:



Glue: noise data.

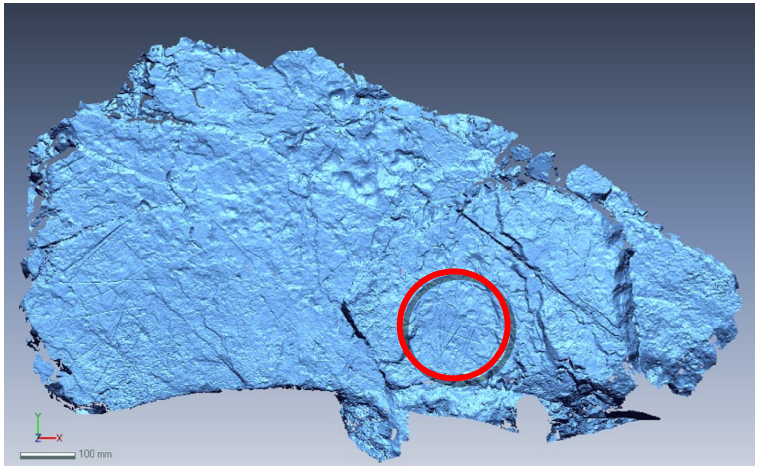


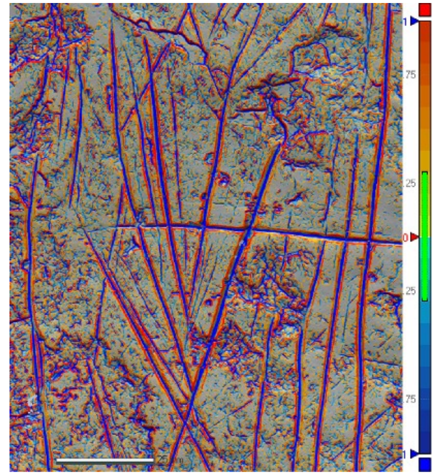
Surface area with distinct characteristics - restoration product (A), wood hardened with fire (B) and natural wood (C): holes and noise data.

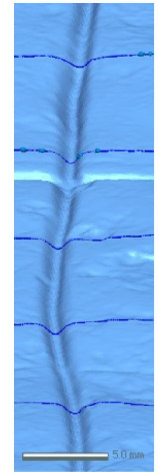


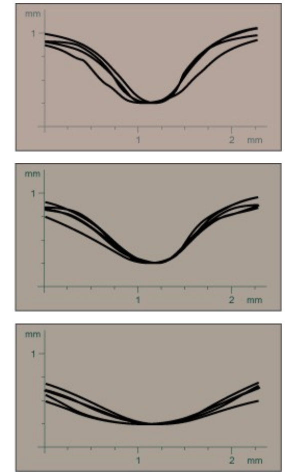
Fragmentation and restoration techniques (surface finishing): holes and noise data.

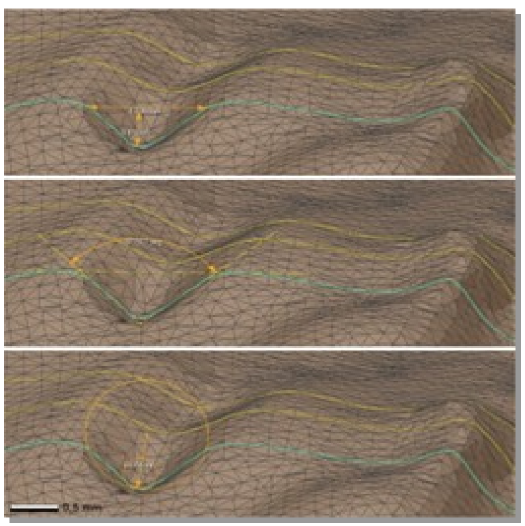
Laboratori d'Arqueologia Quantitativa + Laboratory for Socio Dynamics Simulation / UAB Universitat Autònoma de Barcelona

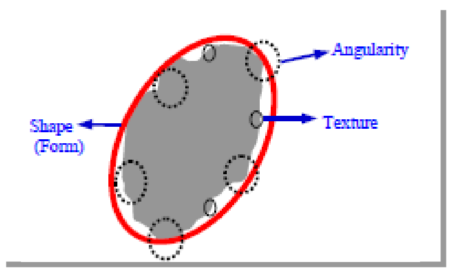






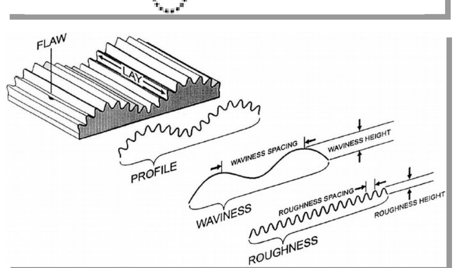


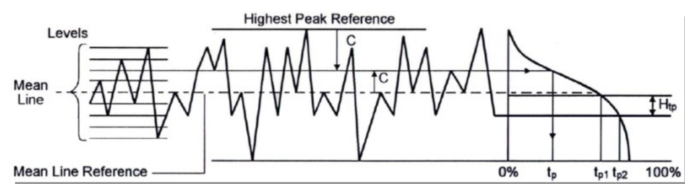




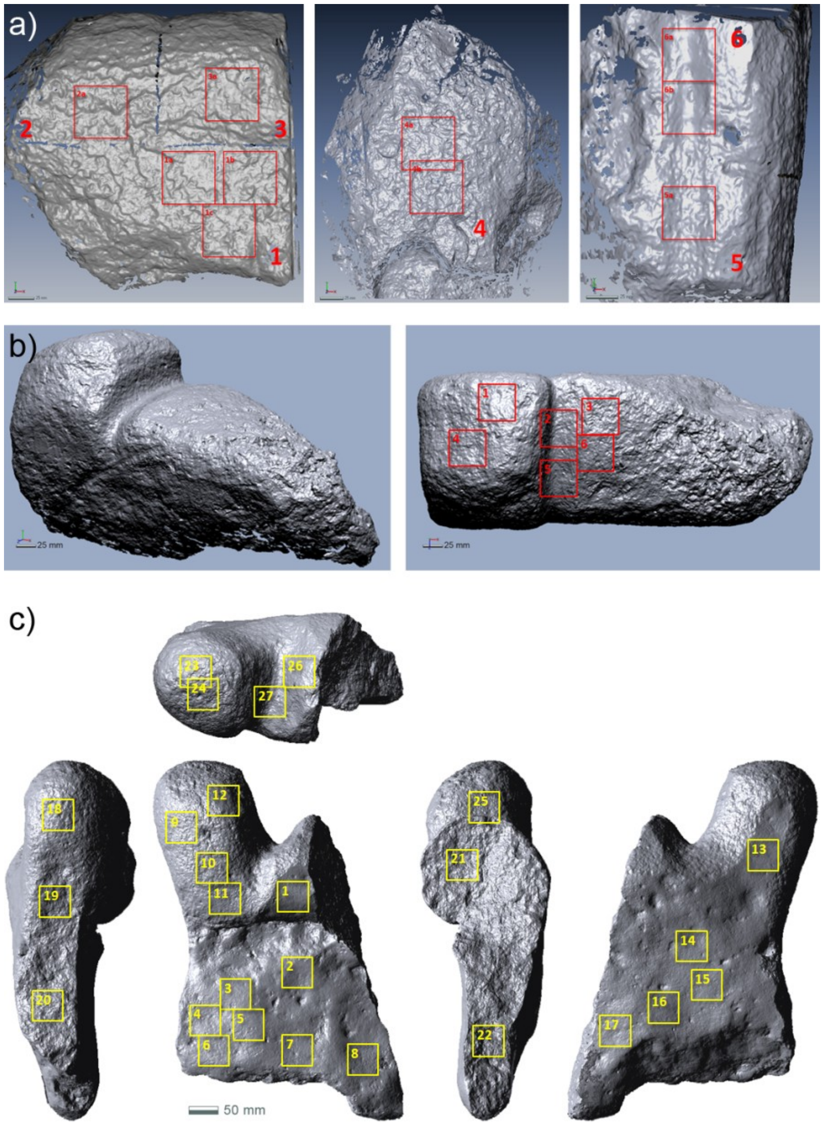
Roundness	$\frac{4Area}{\pi.MaxDiameterer^2}$
Elongation	$\frac{Length}{Width}$
Compactness	$\frac{\sqrt{\left(\frac{4}{\pi}\right) Area}}{MaxDiameterer}$
Quadrature	$\frac{Perimeter}{4\sqrt{Area}}$
Sphericity	$\Psi = \frac{\pi^{\frac{1}{3}}(6V_p)^{\frac{2}{3}}}{A_p}$
Cubeness	$C_d(S) = \frac{n(S) - A(S)/6}{n - (\sqrt[3]{n(S)})^2}$

Average Roughness	$Sa = (1/Ae)\int_0^{Ly}\int_0^{Lx} \lvert Z(x,y)\rvert \, dxdy$
Root Mean Square Roughness	$Sq = \left((1/Ae)\int_0^{Ly}\int_0^{Lx} Z^2(x,y)\, dxdy\right)^{1/2}$
Skewness	$Ssk = \frac{1}{(Sq)^3\, Ae}\int_0^{Ly}\int_0^{Lx} Z^3(x,y)dxdy$
Kurtosis	$Sku = \frac{1}{(Sq)^4\, Ae}\int_0^{Ly}\int_0^{Lx} Z^4(x,y)dxdy$
Texture Aspect Ratio	$Str = \frac{Length-of-fastest-decay-AACV-in-any-direction}{Length-of-slowest-decay-AACV-in-any-direction}$
Texture Direction Surface	$S_{td} = Major-direction-of-Lay-Derived-From-APSD$





3D Digital surface texture sampling



Experimental surfaces
10 samples (50*50 mm) [E]

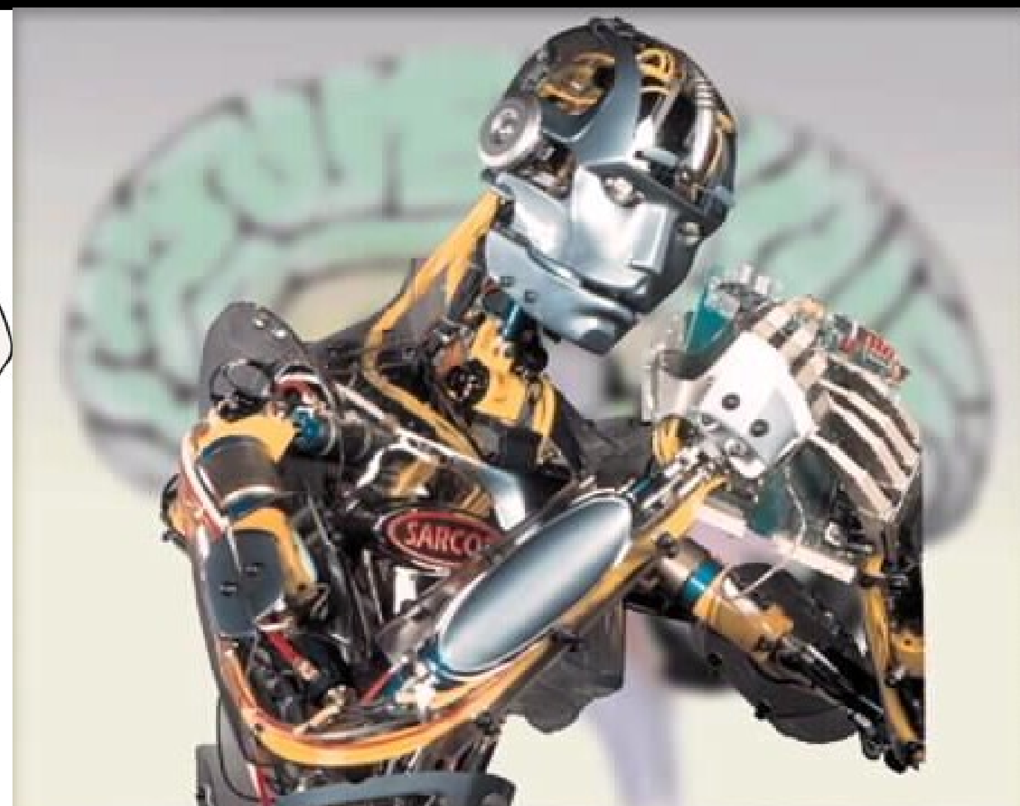
Experimental stela (half sculpted)
6 samples (50*50 mm) [Est]

Archaeological stela (SMB/08 E-17/5/958, fragment A)
27 samples (50*50 mm) [Ast]

3D structured light scanner
(SmartSCAN3D Duo System, Breukmann)

FOV: 450 mm stereo
Resolution: 280 µm
(according to manufacturer)

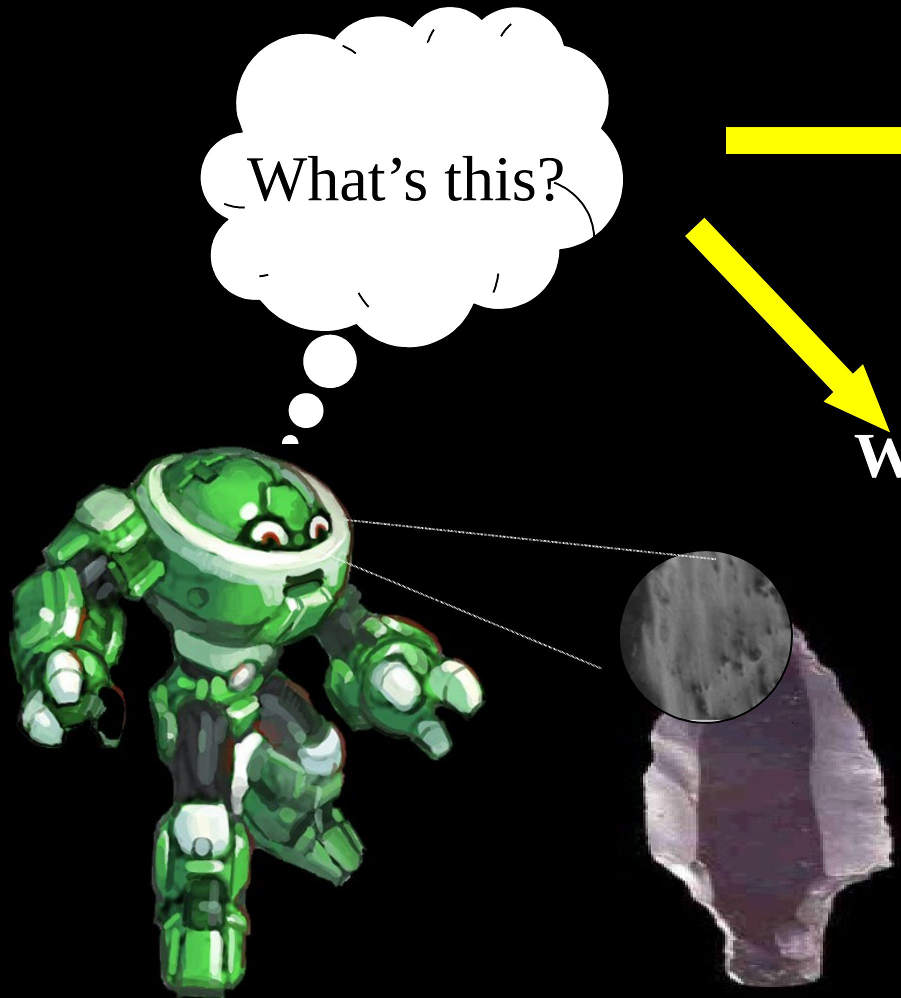
And now, what we can do with all that?



The usual archaeological answer: typology and classification

But Typology is not Classification…..

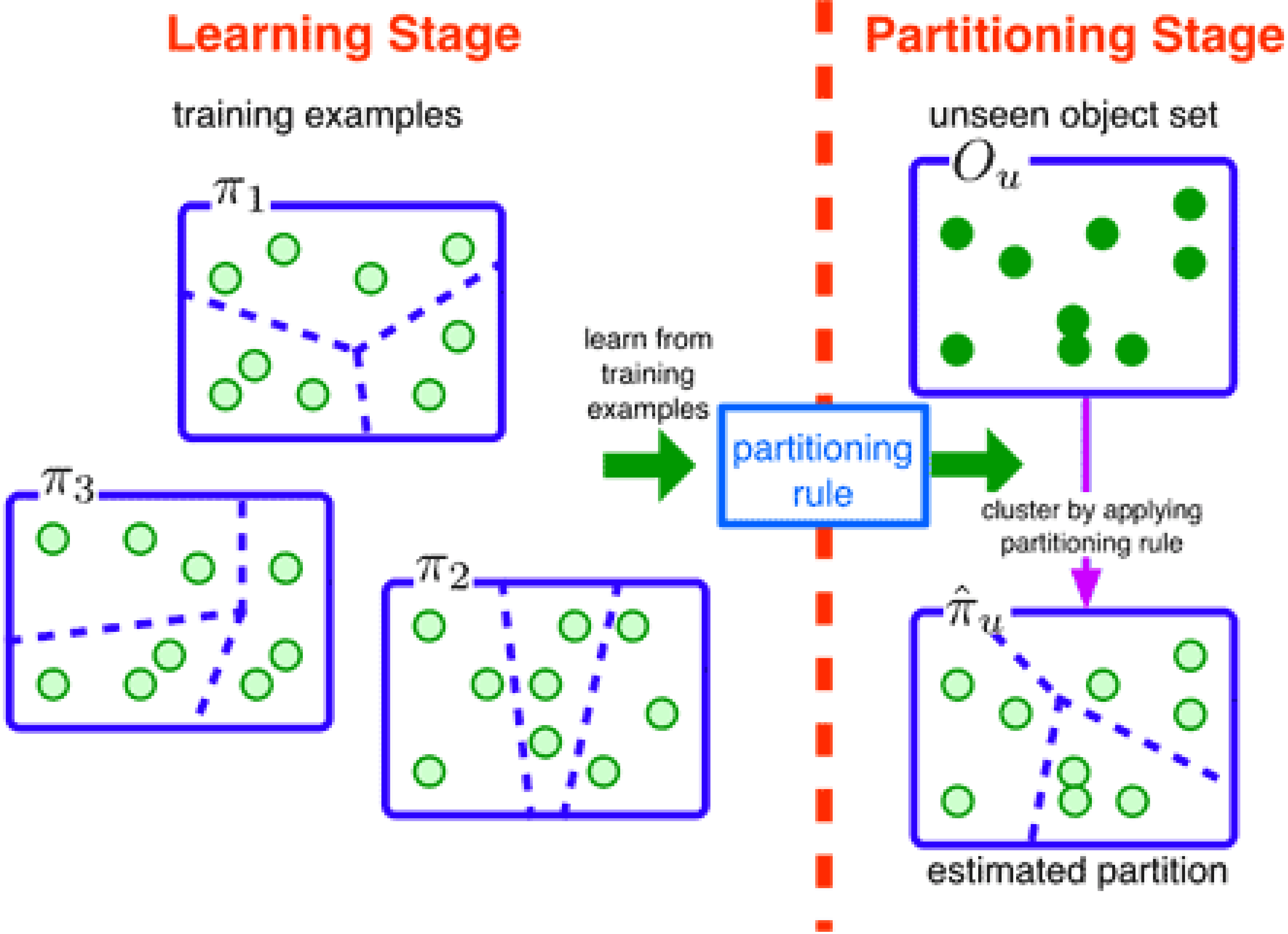
Archaeological “types” do not give “answers nor explanations



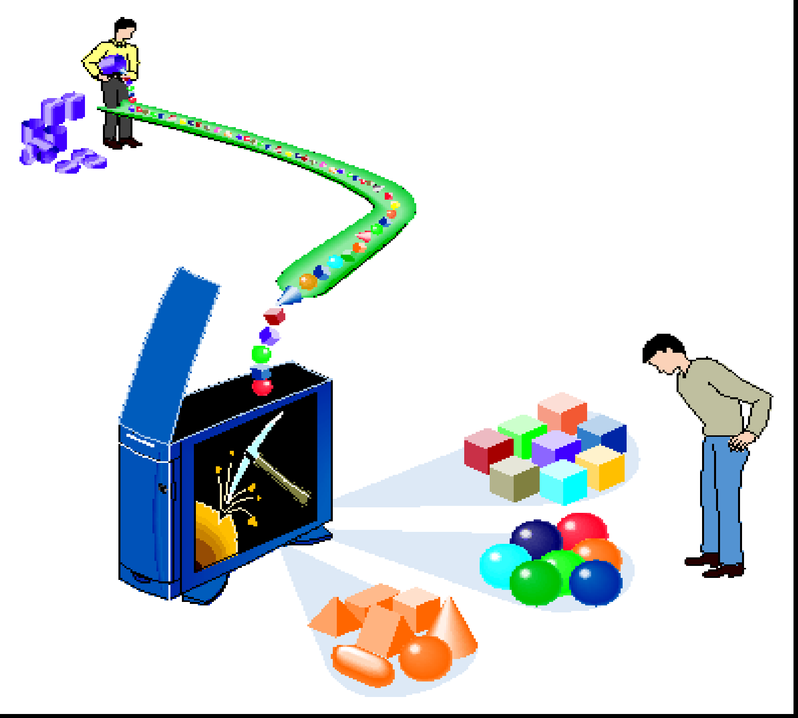
Was it used as a bottle?

Was it used as an arrow point?

YES

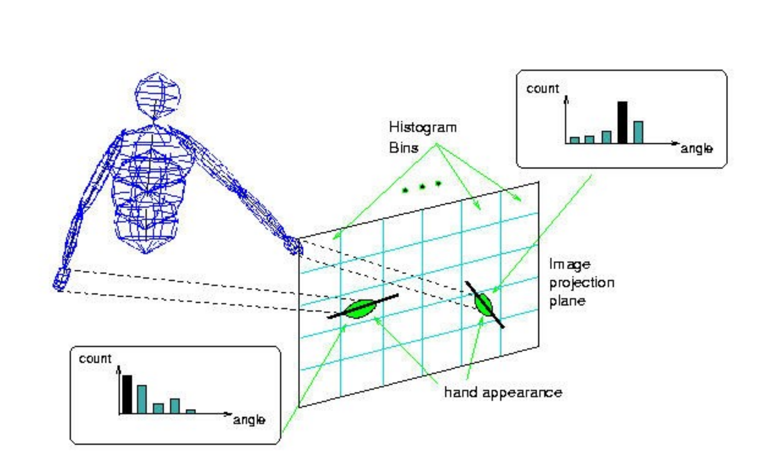


Learning Stage
Partitioning Stage
training examples
π_1
π_3
π_2
learn from training examples
partitioning rule
unseen object set
O_u
cluster by applying partitioning rule
$\hat{\pi}_u$
estimated partition



THE TASK:
to find the common structure in a given perceptual sequence

ASSUMPTION:
the structure that is common across many individual instances of the same cause-effect relationship must be definitive of that group



- From resemblance to similarity

Studying “resemblance”

Two entities are *similar* because they have many *properties* in common. According to this view:

- similarity between two entities increases as a function of the number of properties they share
- properties can be treated as independent and additive
- the properties determining similarity are all roughly the same level of abstractness;
- these similarities are sufficient to describe a conceptual structure: a concept would be then equivalent to a list of the properties shared by most of its instances.

Understanding “Similarity”

Studying “resemblance”

The very idea of similarity is insidious. First, we must recognize that similarity is relative and variable. That means that the degree of similarity between two entities must always be determined relative to a particular domain. Things are similar in color or shape, or in any other domain. There is nothing like overall similarity that can be universally measured, but we always have to say in what respects two things are similar. Similarity judgments will thus crucially depend on the context in which they occur.

Studying “resemblance”

- Measuring “Similarity”

- Dice (Sorensen) coefficient for absence-presence (coded as 0 or positive numbers). Puts more weight on joint occurences than on mismatches.

  When comparing two columns (associations), a match is counted for all taxa with presences in both columns. Using 'M' for the number of matches and 'N' for the the total number of taxa with presences in just one column, we have

  Dice similarity = $2M/(2M+N)$

- Jaccard similarity for absence-presence data: $M/(M+N)$

- The Simpson index is defined as M/N_{min}, where N_{min} is the smaller of the numbers of presences in the two associations. This index treats two associations as identical if one is a subset of the other, making it useful for fragmentary data.

- Kulczynski similarity for presence-absence data:

$$\frac{M/(M+N_1)+M/(M+N_2)}{2}$$

- Ochiai similarity for presence-absence data (binary form of the cosine):

$$\sqrt{[M/(M+N_1)][M/(M+N_2)]}$$

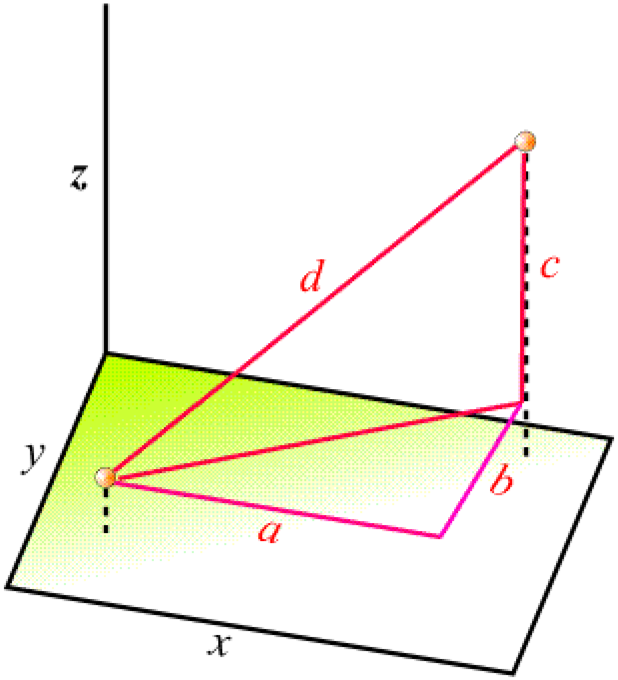
- Bray-Curtis measure for abundance data.

$$Bray-Curtis_{jk}=\frac{\sum_{i=1}^{s}|x_{ij}-x_{ik}|}{\sum_{i=1}^{s}(x_{ij}+x_{ik})}$$

- Cosine distance for abundance data - one minus the inner product of abundances each normalised to unit norm.

Studying "resemblance"

- Measuring *distance* as an alternative to "similarity"

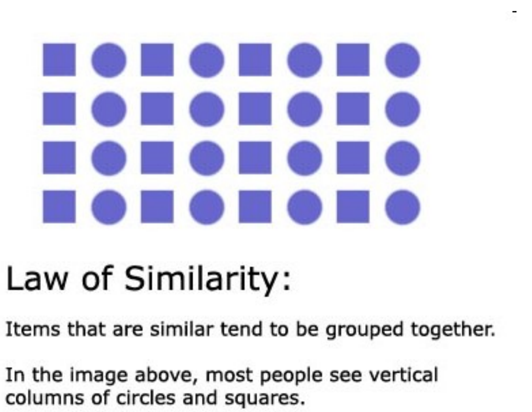


$$d = \sqrt{a^2 + b^2 + c^2}$$

From Clustering To Classification

- The Clustering Principle

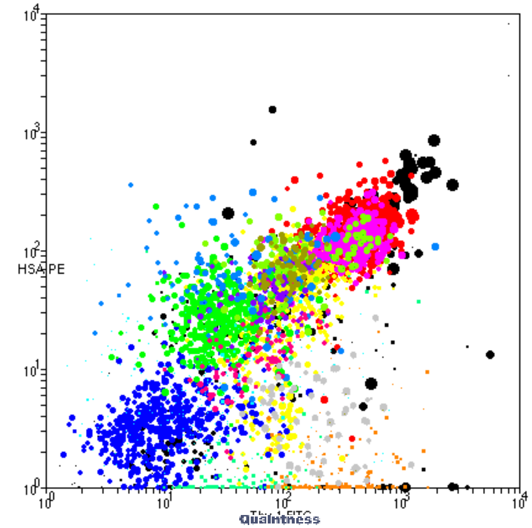
The Clustering Principle:
Internal
Similarity
higher than
External
Similarity

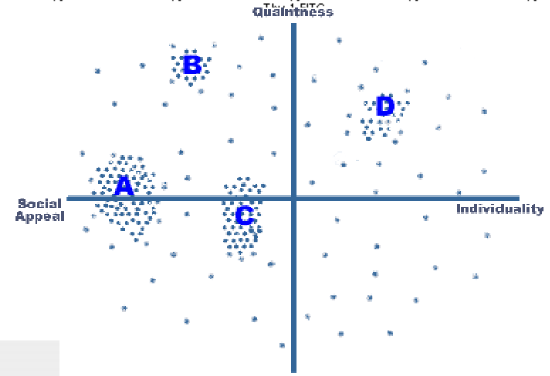


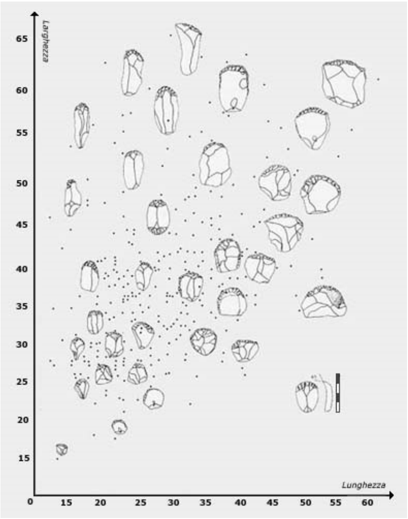
Clustering

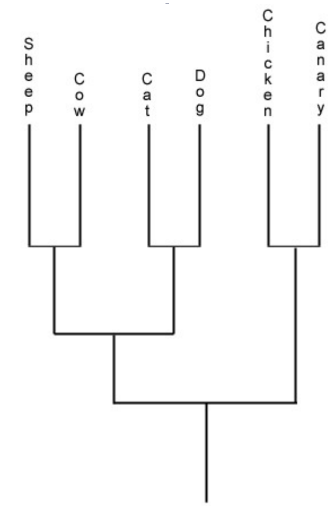
It is the process of grouping input samples in similarity classes.

Thus, one would like to group observations so as to minimize intra-group distances while maximizing inter-cluster distances, subject to the constraints on the number of clusters that can be formed.

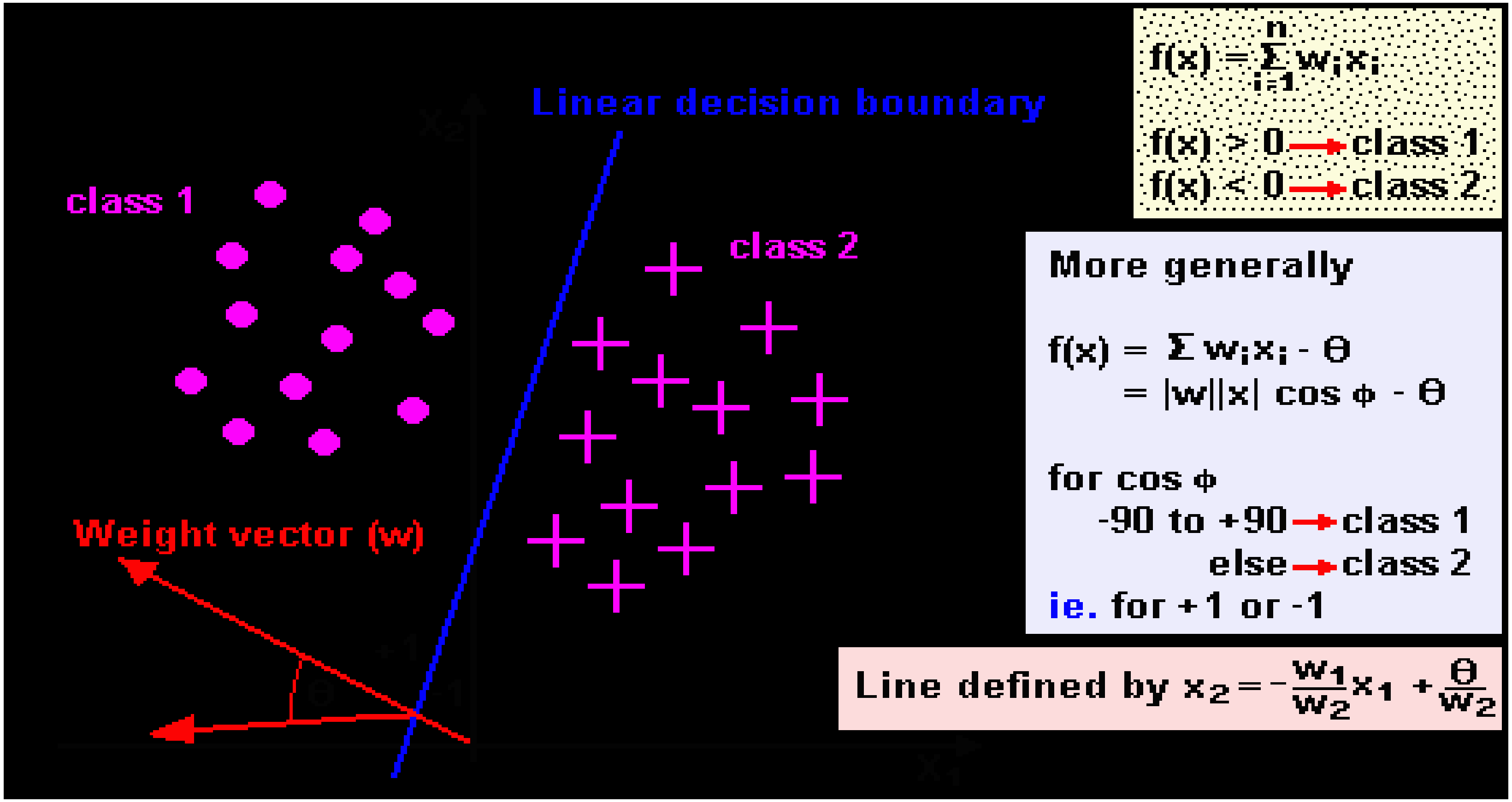




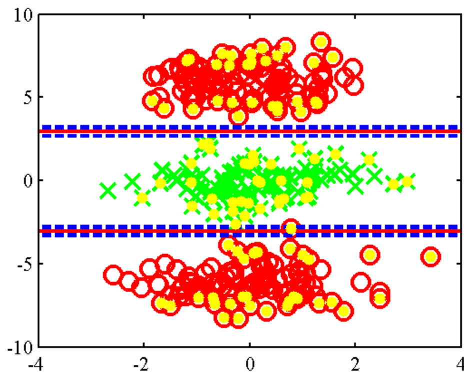


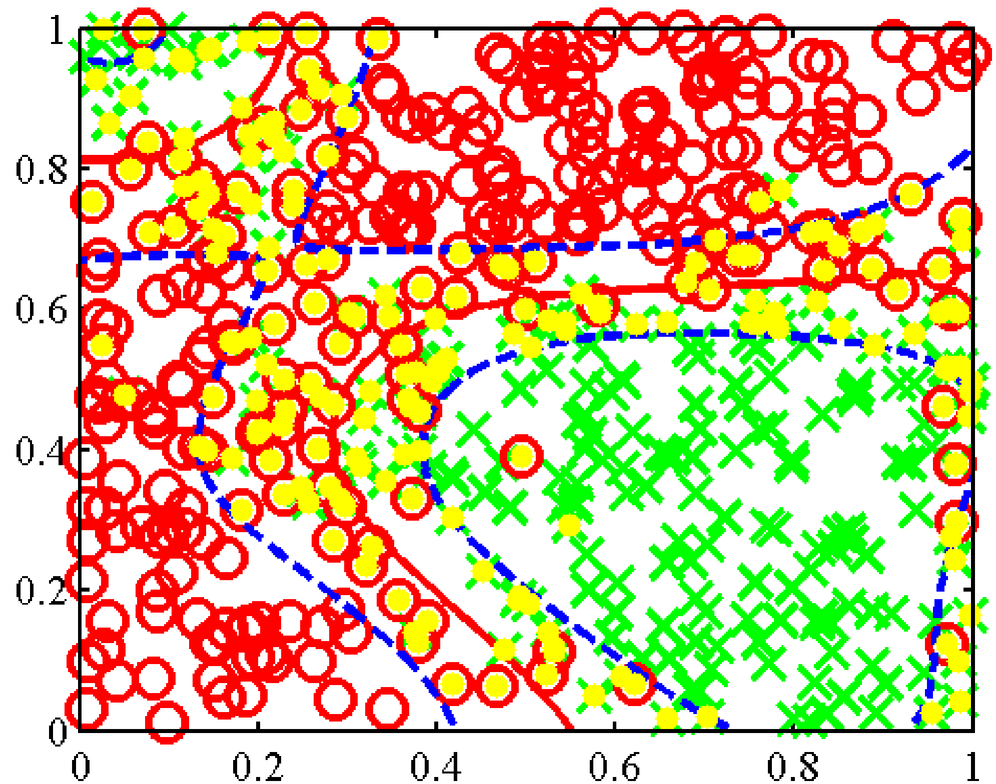


Linear Discrimination



Non-Linear Discrimination





From Clustering to Classification

- What is a “Classification”?

Classification is a form of categorization where the task is to take the descriptive attributes of an observation (or set of observations) and from this to identify the observation within a different phenomenological domain. Hence, the task of the classifier is somehow to partition feature space into disjoint regions that each represents a particular class, cluster, or pattern.

From Clustering to Classification

- What is a “Classification”?

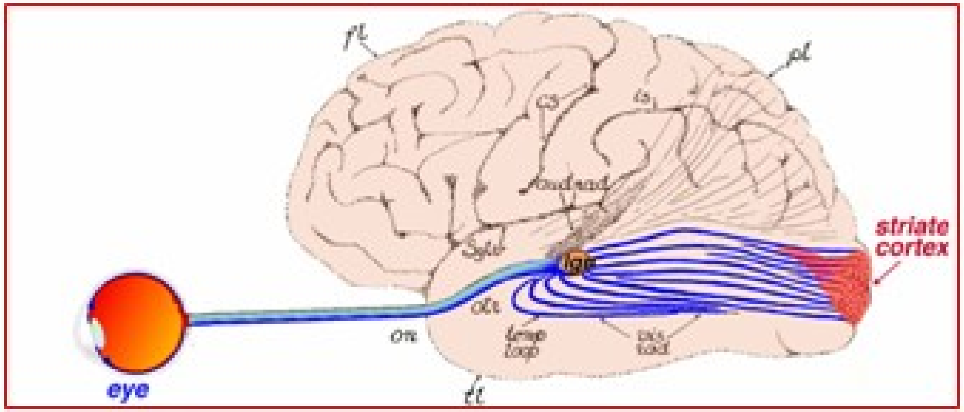
The goal in a classification problem is to develop an algorithm which will assign any artifact, represented by a vector *x*, to one of *c* classes (chronology, function, origin, etc). The problem is to find the best mapping from the input patterns (descriptive features) to the desired response (classes).

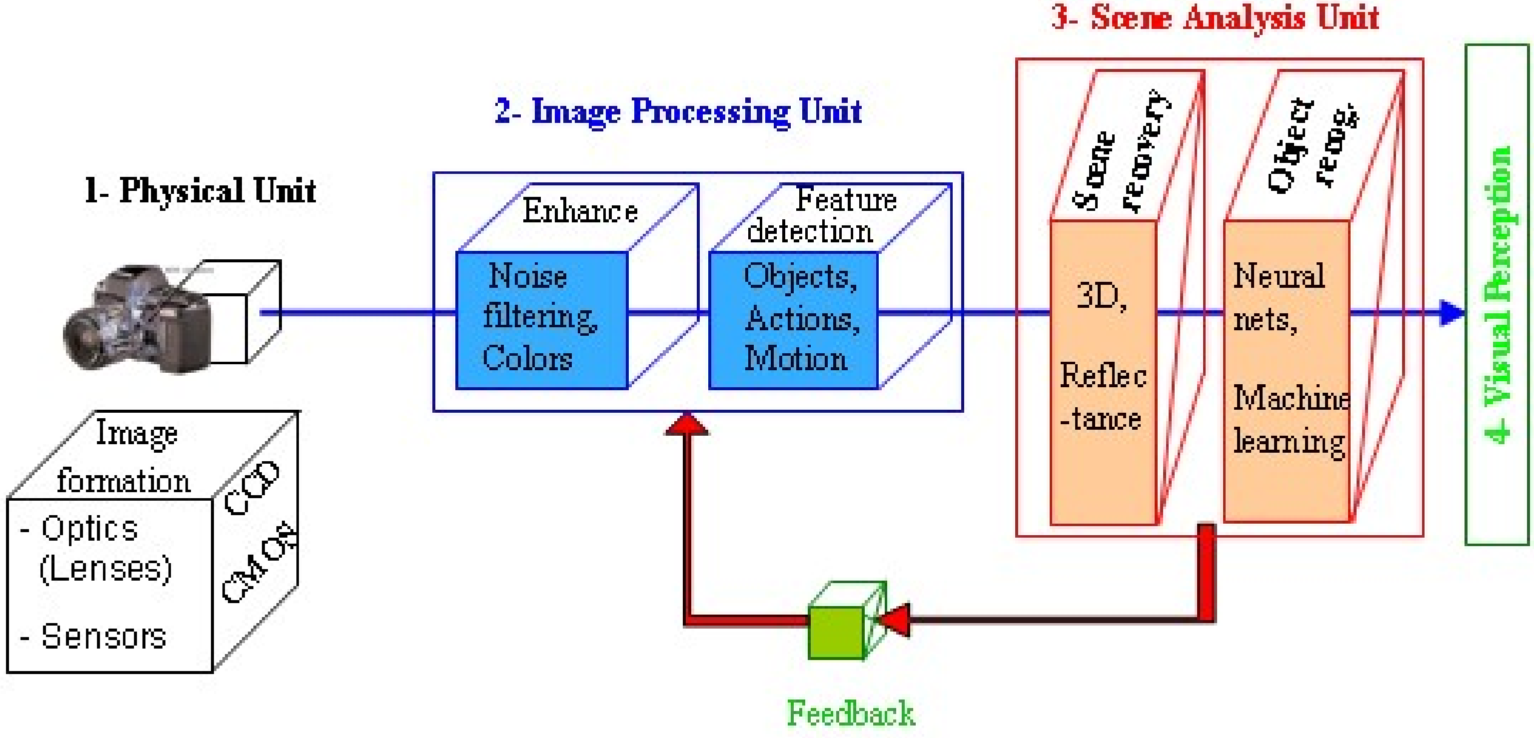
From Clustering to Classification

- What is a "Classification"?

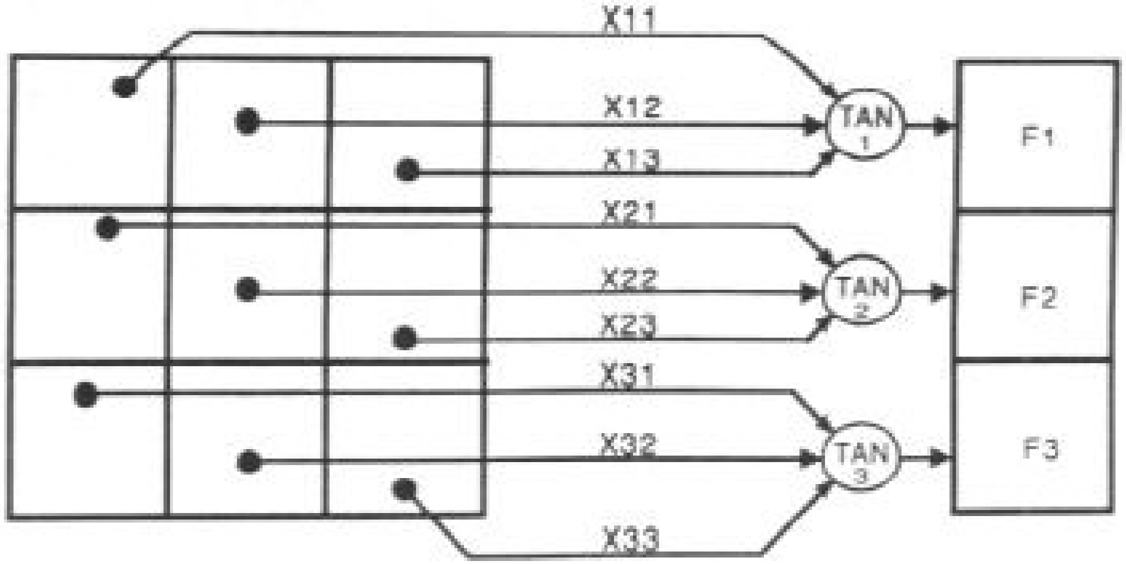
The purpose of the classification problem is to estimate the probability of membership of the case in each class. The objective is to build a model with significant predictive power. It is not enough just to find which relationships are statistically significant. That explains why classification and prediction are frequently interrelated. A prediction of an historical event is equivalent to a classification within a given set of events.

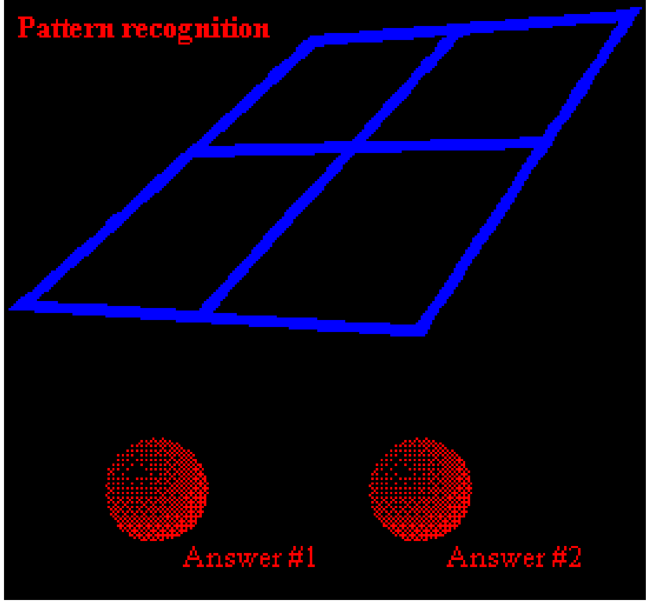
COMPUTER VISION

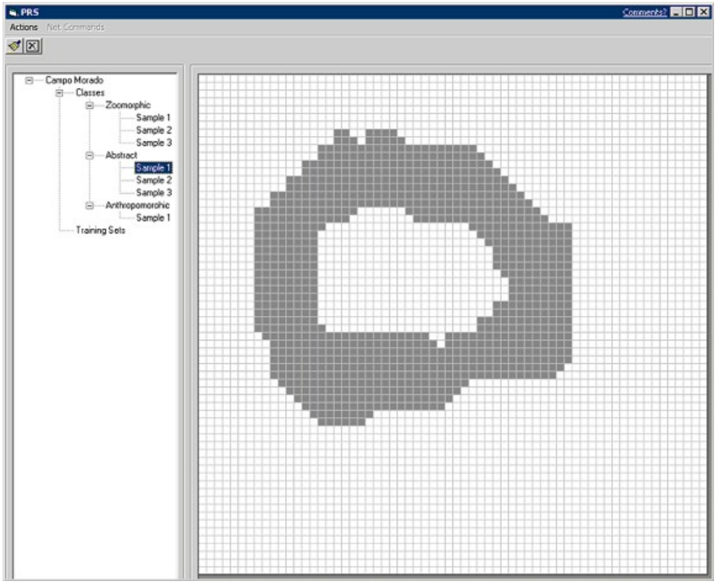


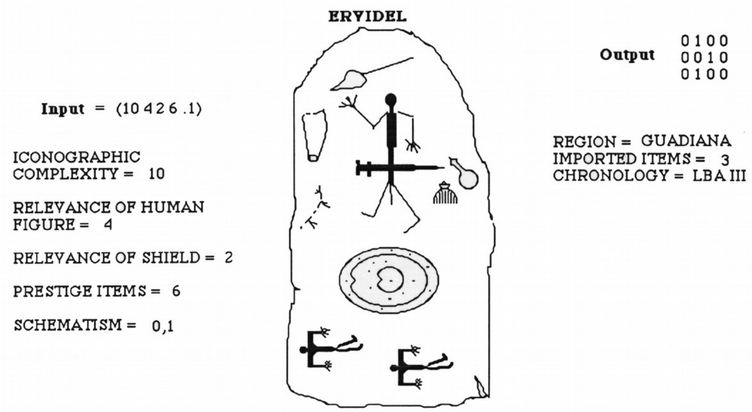


Stages of Computer Vision, Copyright ©2005 F. Keyrouz







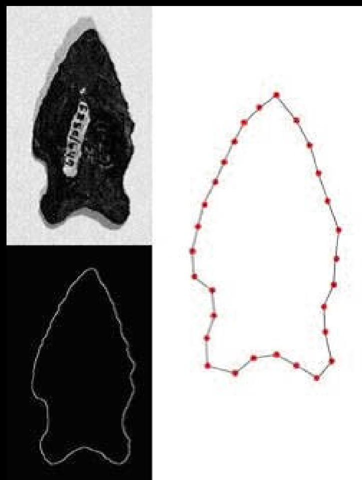


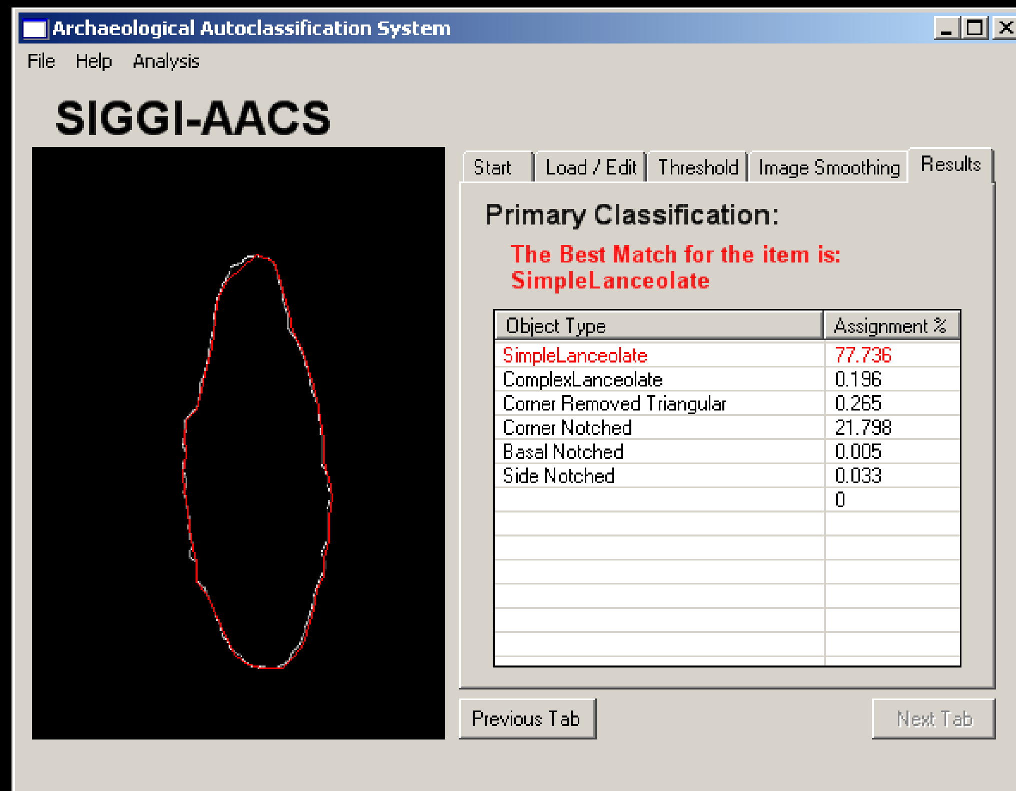
J.A. BARCELO, 1995 Back-propagation algorithms to compute similarity relationships among archaeological artifacts. In *Computer Applications in Archaeology*.

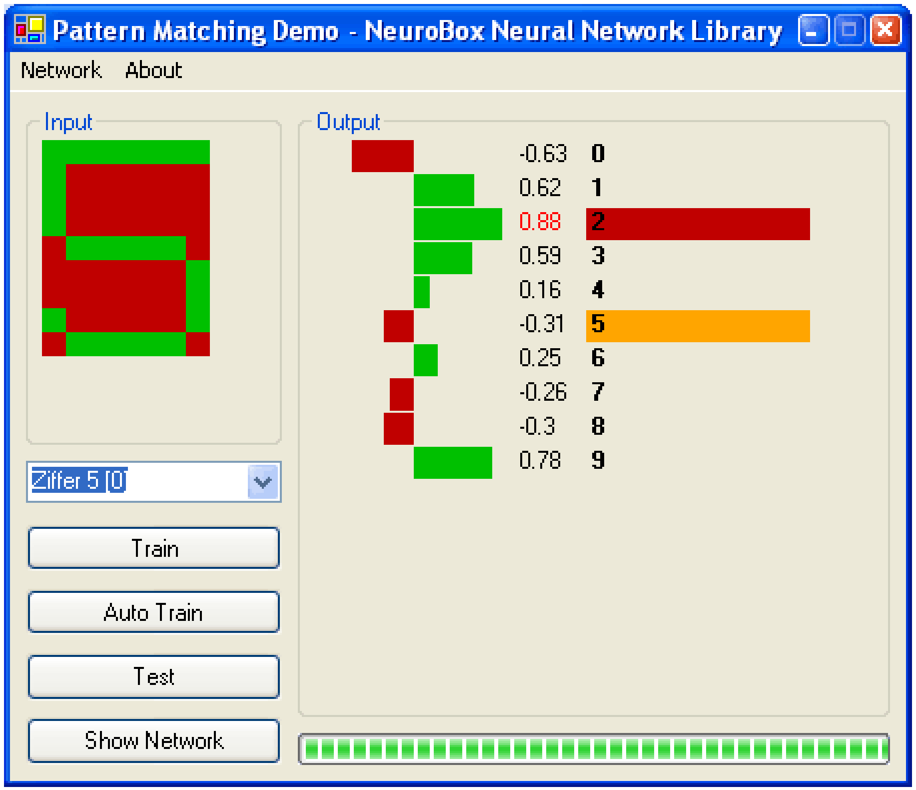
Edited By r J. Wilcock y K. Lockyear. Oxford: British Archaeological Reports.

DIAZ,D., CASTRO,D., 2001, "Pattern Recognition applied to Rock Art".
In *Archaeological Informatics: Pushing the Envelope.* Edited by Göran Burenhult.
Oxford: ArchaeoPress (BAR Int. Series S1016)., pp. 463-468.

LOHSE, E.S., SCHOU,C., SCHLADER,R., SAMMONS,D, 2004, “Automated Classification of Stone projectile Points in a Neural Network”. In *Enter the Past. The e-way into the four dimensions of culture heritage*. Edited by Magistrat der Stadt Wien-Referat Kulturelles Erbe-Städtarhchäologie Wien. Oxford, ArcheoPress (B AR Int. Series, S1227), pp. 431-437).







The general idea is that a neural network can be fed with visual inputs (images), and it will output a shape-based recognition of the visual features present in that input.

Kashyap, H.K., Bansilal,P., Koushik A.P., 2003, **Hybrid Neural Network Architecture for Age Identification of Ancient Kannada Scripts.** *Proceedings of the 2003 IEEE International Symposium on Circuits and Systems (ISCAS 2003)*, Vol. 3, Page(s): 423-426, May 25-28, 2003.

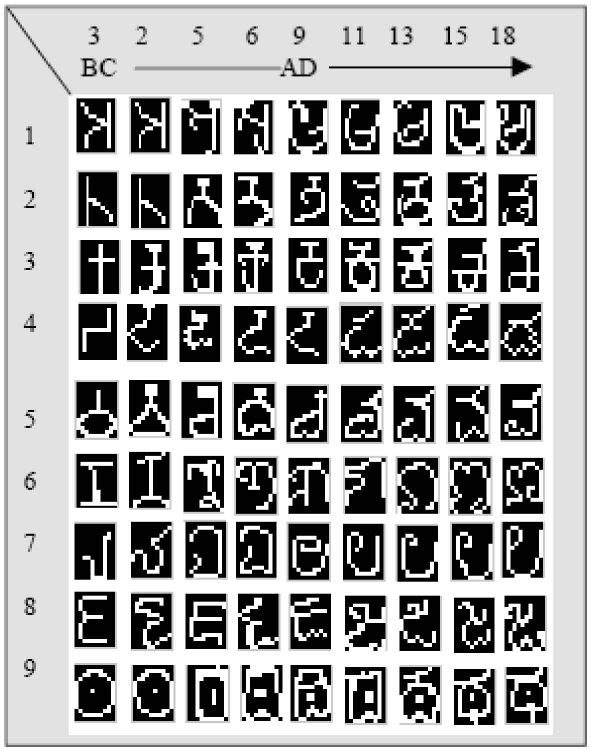


Figure 6. Set of Characters ranging from 3rd century BC to 18th Century AD.

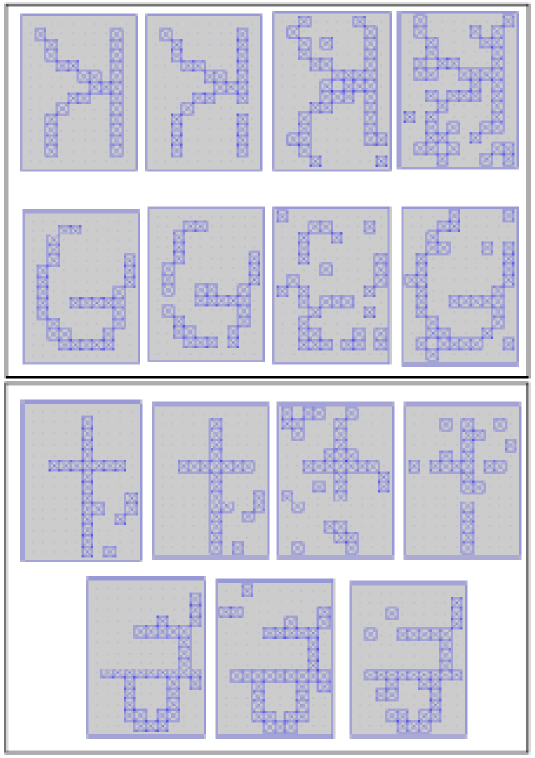
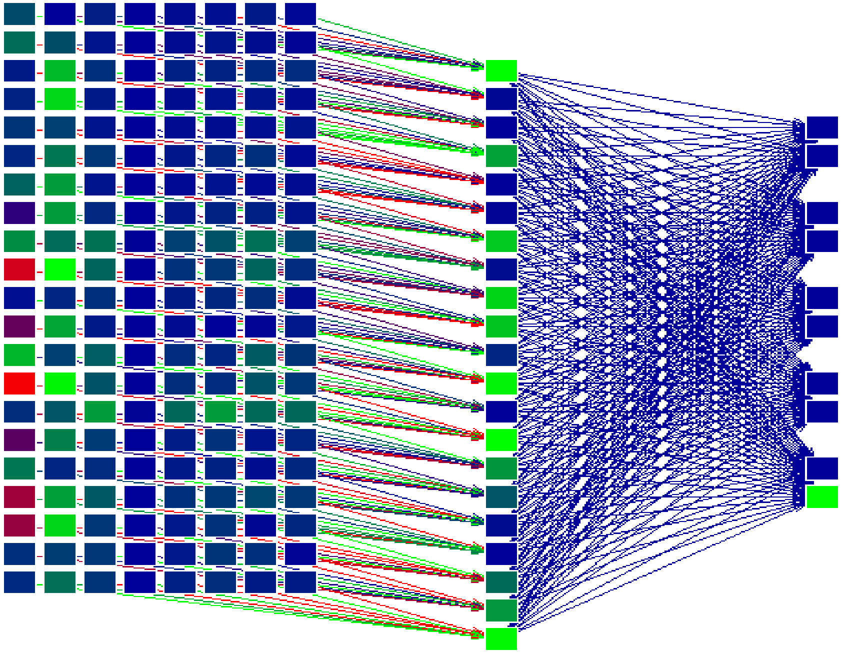


Figure 7. Images accurately classified by PNN.

An Artificial Neural Network for studying ancient Indian documents written in Kannada, a language of southern India, which is as old as 5th century AD.

(Kashyap et al., 2003).


Input Image



From Classification to Typology

- The idea of Typology. A set of ordered Prototypes

Prototype. It is an individual instance of some entity serving as a typical example, for other entities of the same category. When the regularities extracted for a given archaeological data share a common set of attributes, this set can be said to define a prototype.

From Classification to Typology

Can we define a “class” or “type” from a cluster of similar objects?

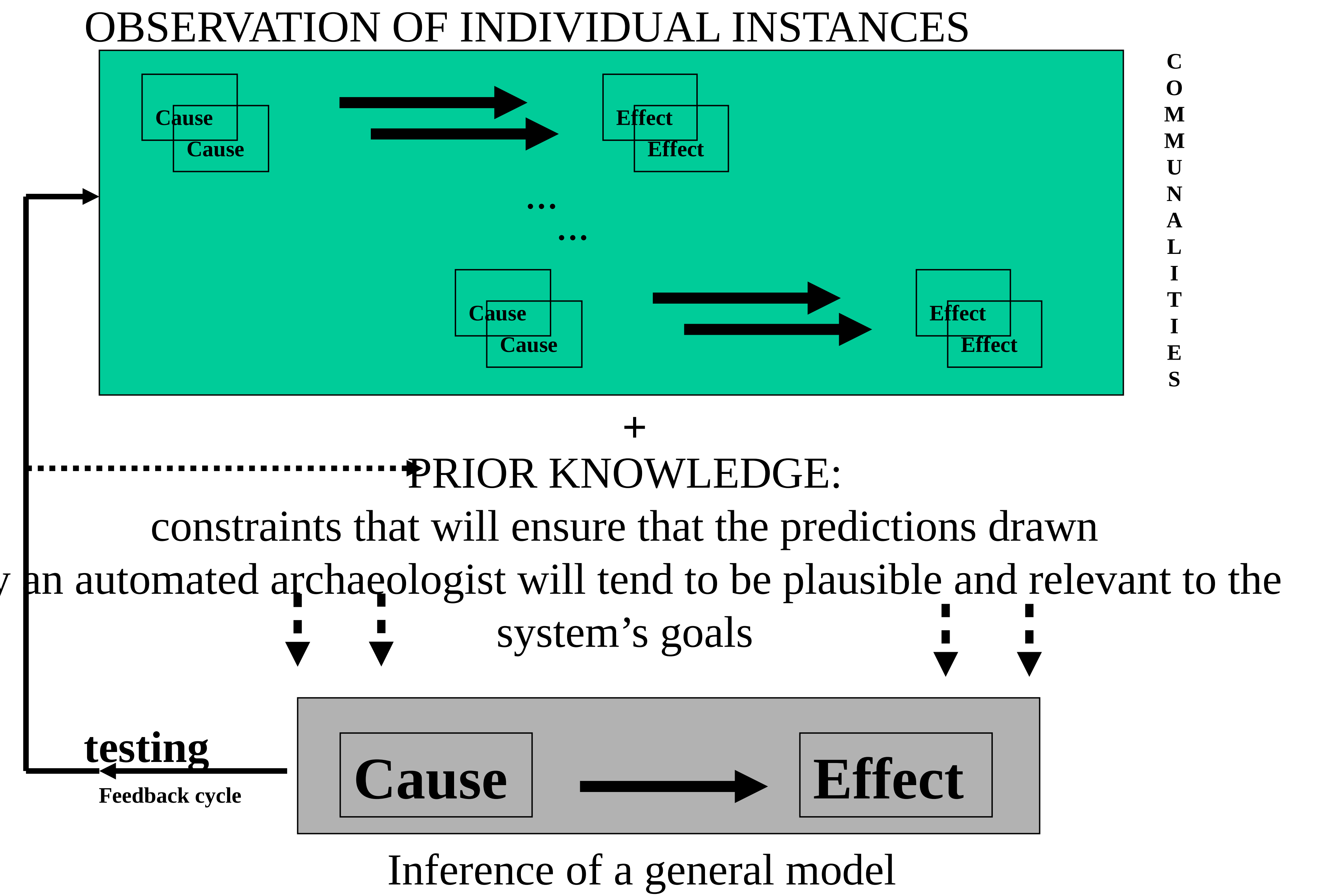
In clustering, a set of explanations will be modeled by first describing a set of prototypes, then describing the objects using these prototypical descriptions. Each description gives the probabilities of the observable features, assuming that what has been perceived belongs to a group composed of similar looking percepts. The prototype descriptions are chosen so that the information required to describe objects in the class is greatly reduced because they are “close” to the prototype.

Learning

We should learn CAUSAL ASSOCIATIONS.

B depends on *A* if *B* is consequence of *A*.

This relationship between EFFECT and CAUSE is not necessary a formal relationship. At least not always. It should exist some type of association, but we do not need that that association follows formal criteria. Obviously, the more formal the dependence between EFFECT and CAUSE, the greater validity we will grant to the problem solution.


OBSERVATION OF INDIVIDUAL INSTANCES
Cause
Cause
Effect
Effect
…
…
Cause
Cause
Effect
Effect
COMMUNALITIES
+
PRIOR KNOWLEDGE:
constraints that will ensure that the predictions drawn
y an automated archaeologist will tend to be plausible and relevant to the
system's goals
testing
Feedback cycle
Cause
Effect
Inference of a general model

x

Input#1	Input#2	Input#3
0.9	0.7	0.8
0.0	0.3	0.6
0.4	0.7	0.2
0.2	0.6	0.7
0.6	0.3	0.1
0.8	0.2	0.5
0.2	0.6	0.9
0.2	0.9	0.2
0.4	0.9	0.6
0.3	0.9	0.0
0.7	0.4	0.1
0.4	0.4	0.7
...	...	...
...	...	...
...	...	...
0.3	0.1	0.9

y

Output
0.5
0.4
0.2
0.1
0.5
0.5
0.7
0.3
0.0
0.1
0.3
0.2
...
...
...
0.9

Arqueología = CIENCIA EXPERIMENTAL

FUNCTIONAL ANALYSIS

The function of a certain item is – or should be – what it is best able to do (or be) given its physical constitution and its context.

D. Dennet *Design Stance*.

FUNCTIONAL ANALYSIS

An object's *use* can be defined as the exertion of control over a freely manipulable external object with the specific intention of:

(1) altering the physical properties of another object, substance, surface or medium via a dynamic mechanical interaction, or

(2) mediating the flow of information between the tool user and the environment or other organisms in the environment.

To infer “functionality” from perceived properties we need a combination of three kinds of information:

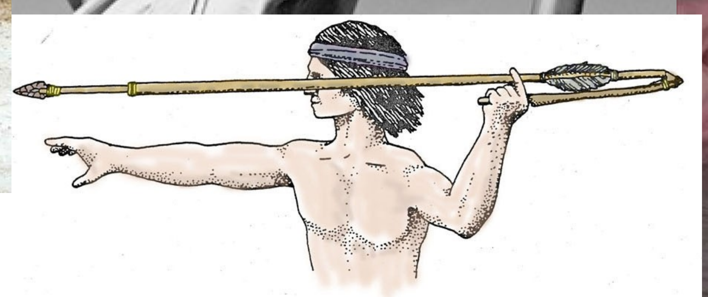
- Knowledge about how the designers intended to design the artifact to have the function
- Knowledge about how the makers determined the physical structure of that artifact on the basis of their technological abilities
- Knowledge about how the artifact was determined by its physical structure to perform that function

FUNCTIONAL ANALYSIS.

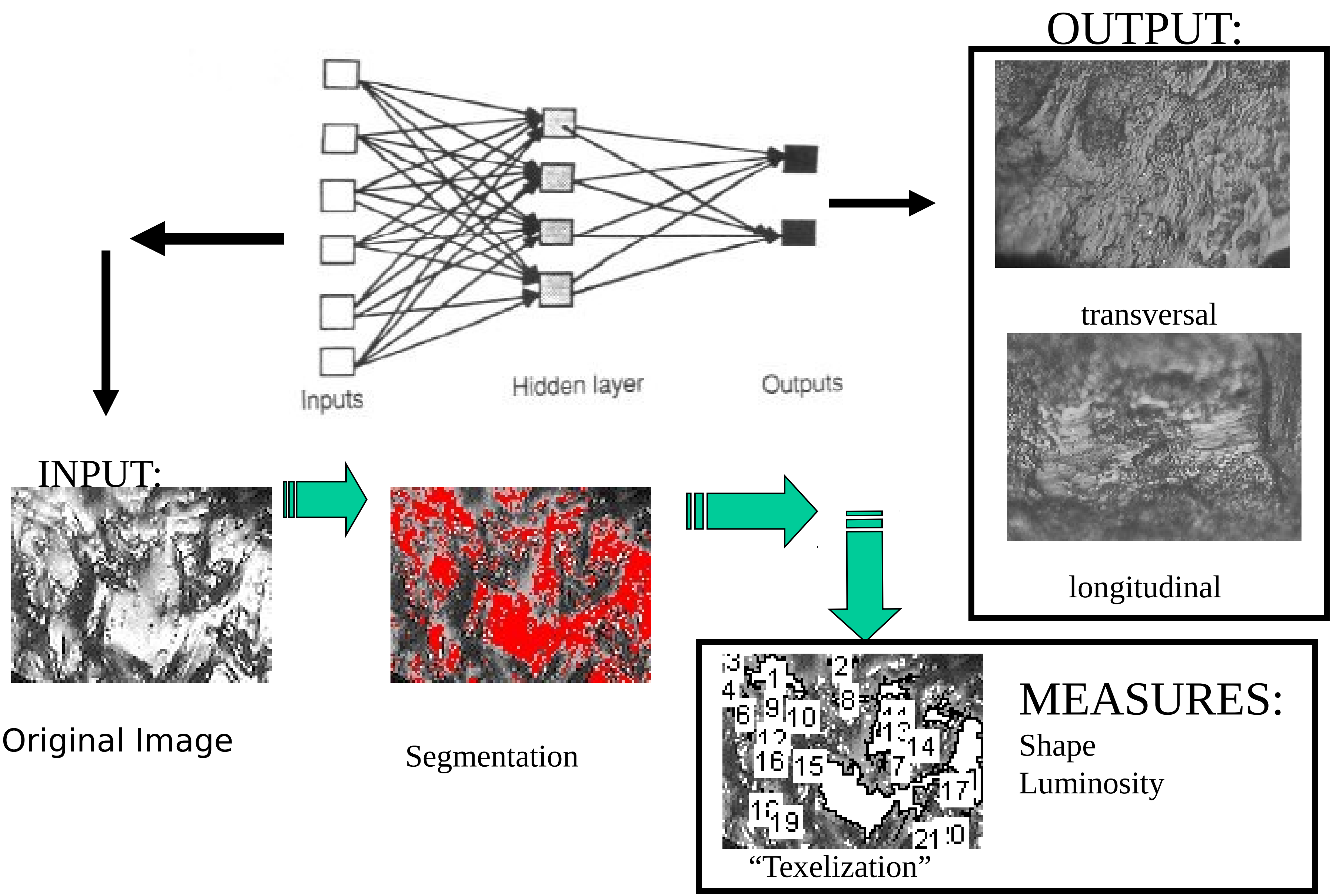
DIRECTLY INTERACTING WITH REAL OBJECTS

The constraints that are relevant in function of the archaeological entity fall into different categories, which would include the following (St. Amant 2002, Bicici and St. Amant 2003):

- *Spatial* constraints describe the spatial relationships associated with a tool and its use in an environment. For example, to use a hammer one needs enough room to swing it.
- *Physical* constraints describe physical relationships in the use of the tool, such as weight or size.
- *Dynamic* constraints describe movement- or force-related properties of tool use. For example, one needs to swing a hammer with appropriate speed in its use.



The PEDRA System

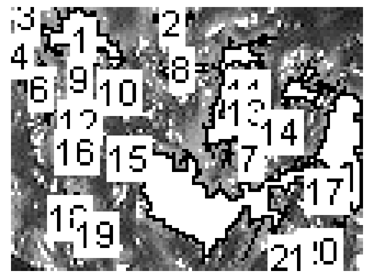


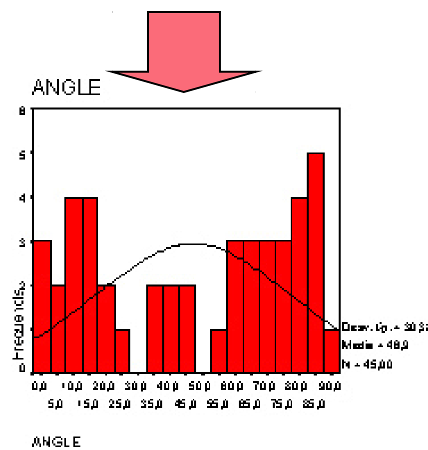
DESCRIBING TEXTURE

Central Tendency texture values

In each picture we calculate the mean and standard deviation values of texel features

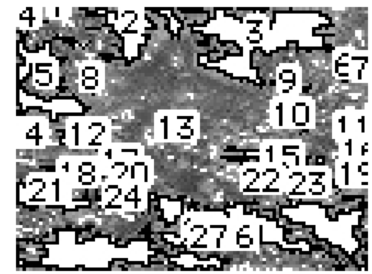
transversal

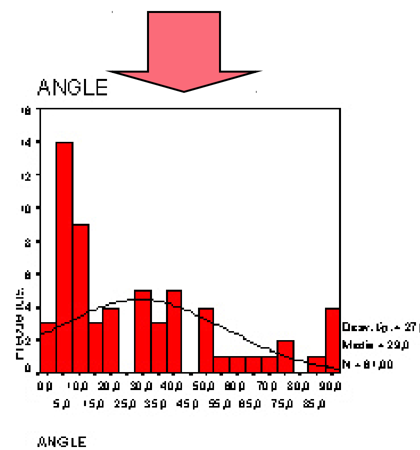




Mean = 48.9
SD = 30.38

longitudinal





Mean = 29
SD = 27.01

NEURAL NETWORKS. The PEDRA Project

PEDRA. (*Stone in Catalan)*

Output / Desired	*KYNEMAT(T)*	*KYNEMAT(L)*
KYNEMAT(T)	**143**	**86**
KYNEMAT(L)	**26**	**177**

Performance	***TRANSVERS***	***LONGITUD***
MSE	0,173922583	0,174325181
NMSE	0,730265892	0,731956322
MAE	0,360646928	0,361481759
Min Abs Error	0,000365206	0,000365206
Max Abs Error	0,962687106	0,962687106
r	0,61404546	0,61404546
Percent Correct	**84,6153**	**67,3003**

PATTERN RECOGNITION

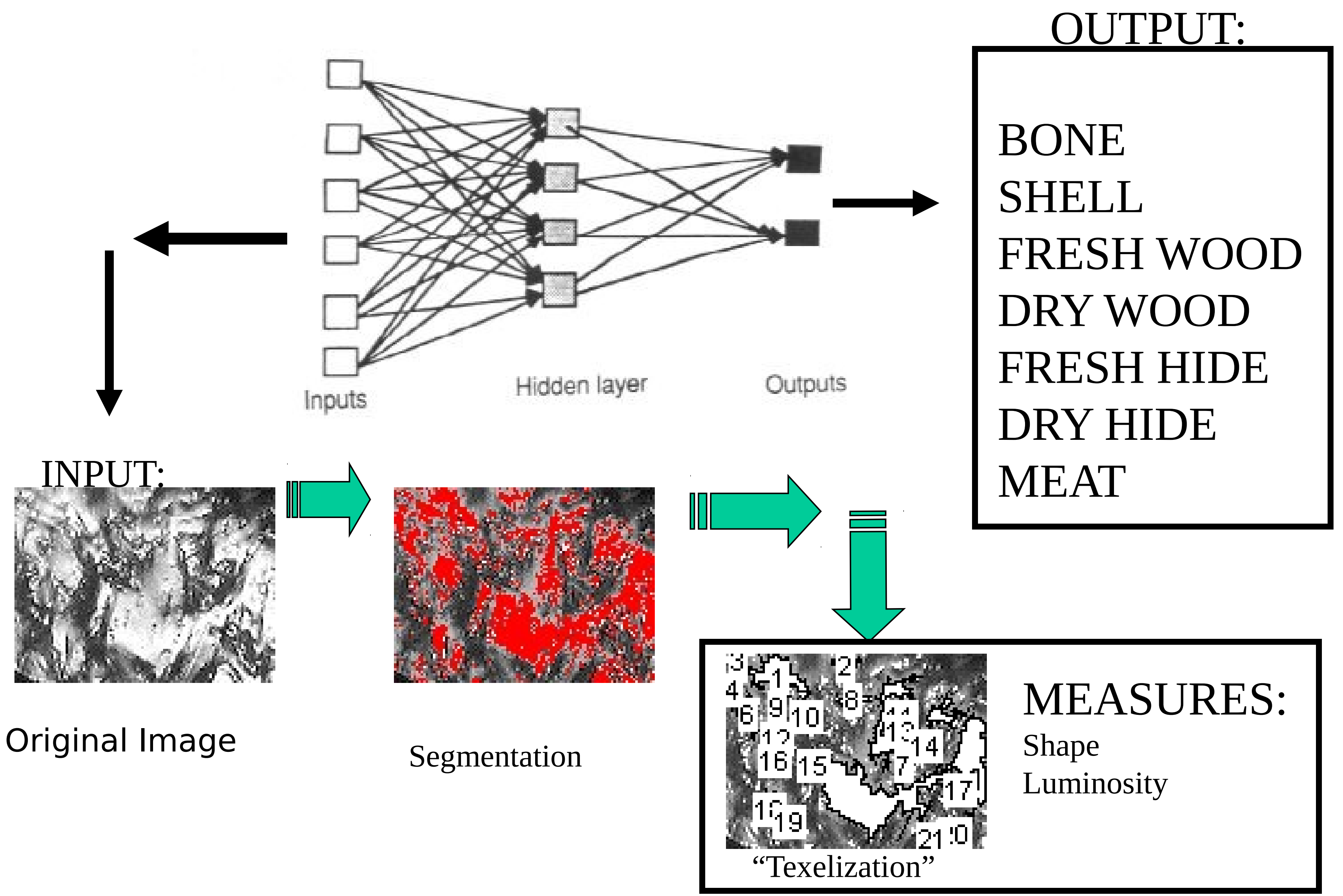
The network has correctly learn to distinguish use kynematics

LONGITUDINAL

TRANSVERSAL

Edge orientation

Edge orientation



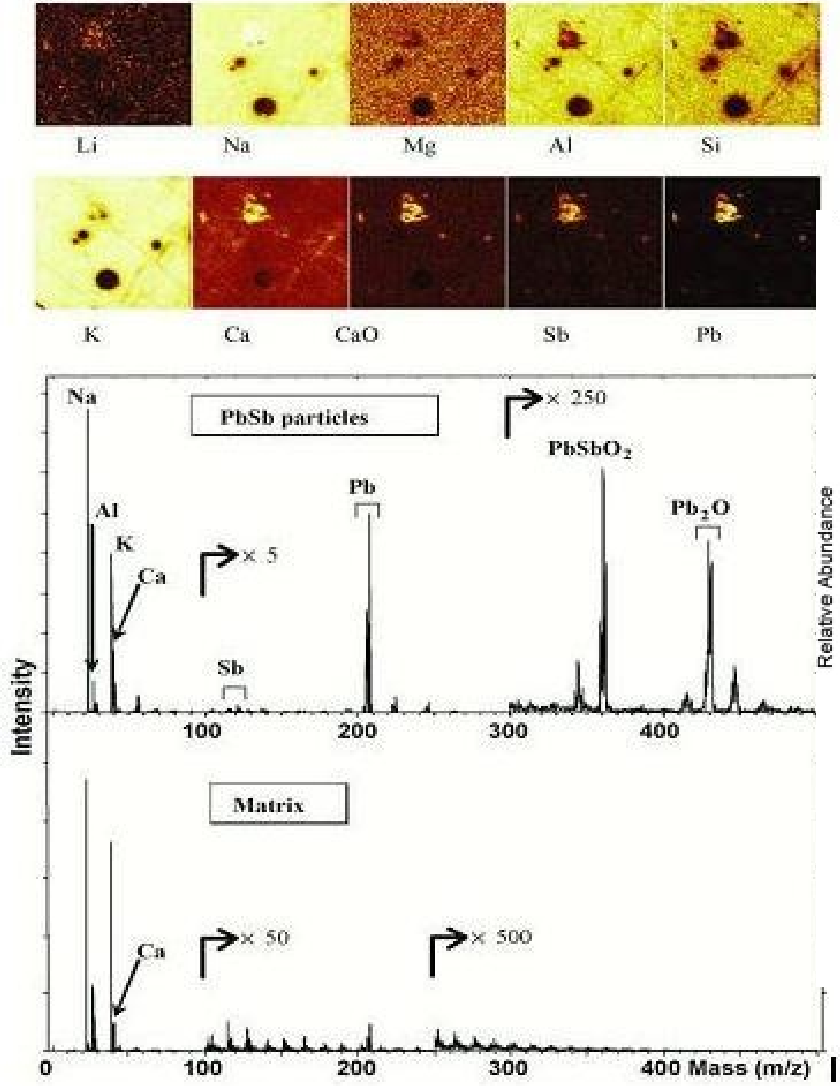
OUTPUT:
BONE
SHELL
FRESH WOOD
DRY WOOD
FRESH HIDE
DRY HIDE
MEAT
Inputs
Hidden layer
Outputs
INPUT:
Original Image
Segmentation
MEASURES:
Shape
Luminosity
"Texelization"

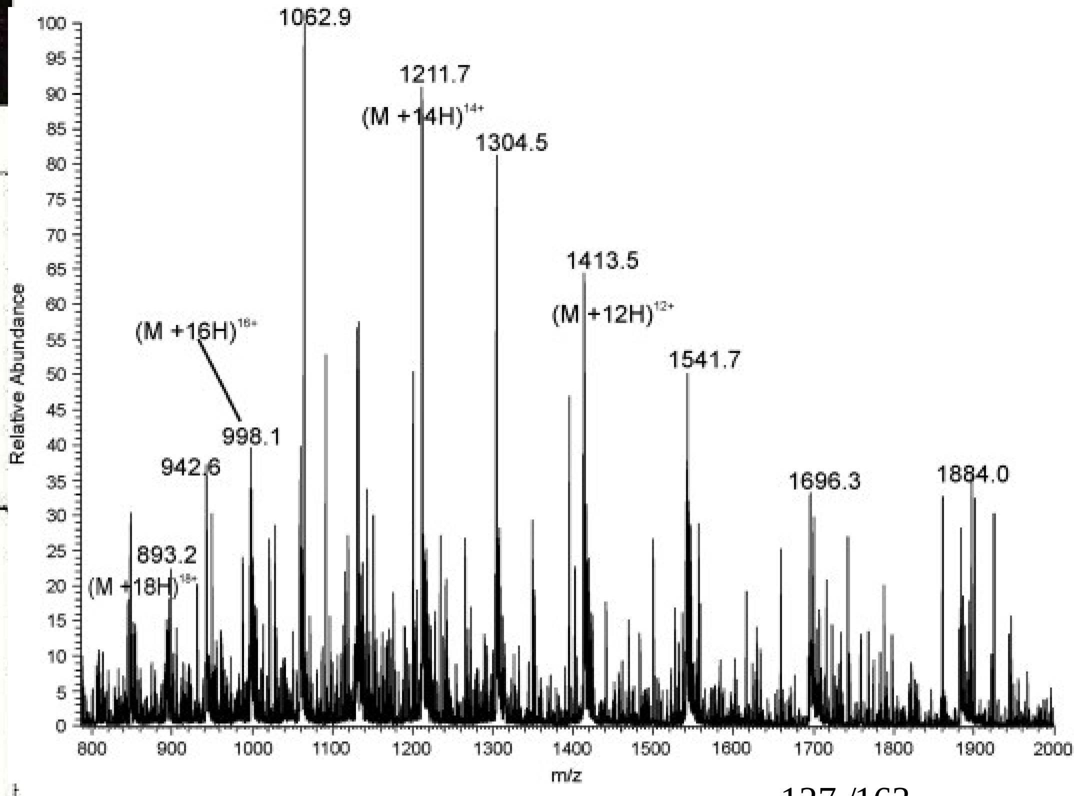
Output / Desired	BONE	BUTCHERY	DRY HIDE	DRY WOOD	FRESH HIDE	FRESH WOOD	SHELL
BONE	55	0	0	6	1	3	10
BUTCHERY	8	43	4	2	5	1	0
DRY HIDE	13	4	46	6	0	6	3
DRY WOOD	13	1	12	43	1	13	4
FRESH HIDE	3	17	7	3	18	0	0
FRESH WOOD	10	1	5	6	0	28	8
SHELL	20	1	6	5	0	11	44

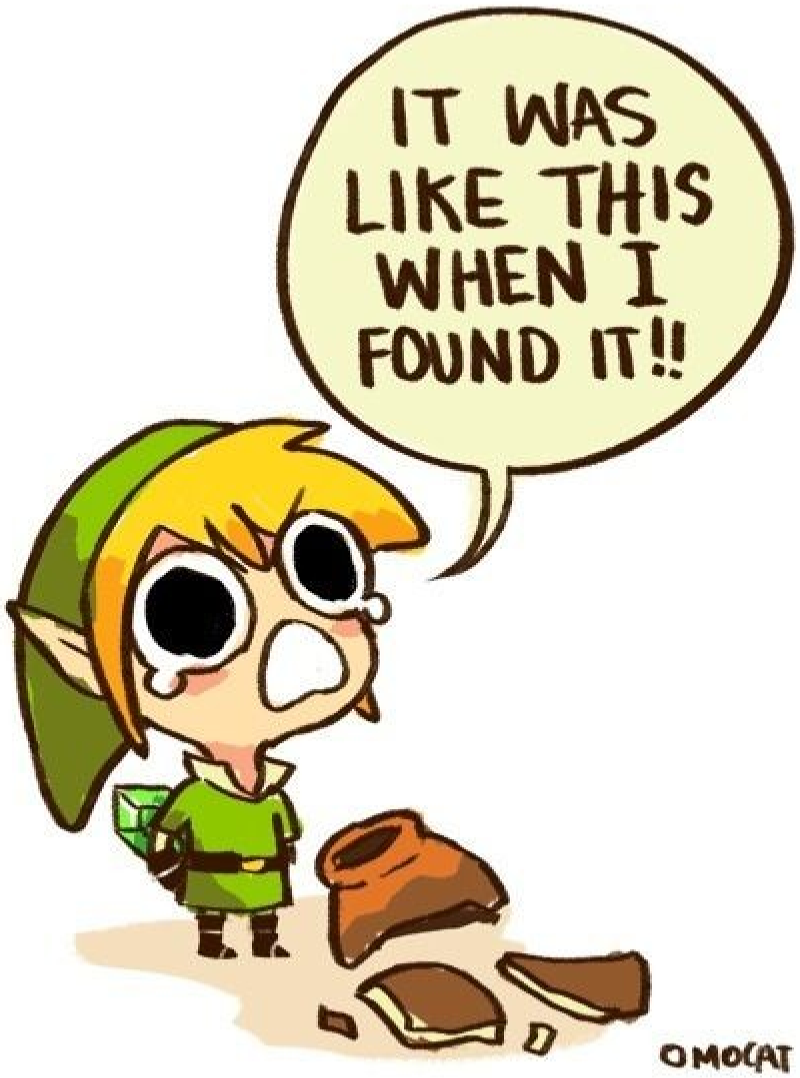
Performance	BONE	BUTCHERY	DRY HIDE	DRY WOOD	FRESH HIDE	FRESH WOOD	SHELL
MSE	0,1433	0,0626	0,0983	0,0962	0,0405	0,0852	0,0892
NMSE	0,7731	0,5364	0,7271	0,7844	0,8473	0,7795	0,7449
MAE	0,237	0,1455	0,1966	0,20543	0,1137	0,1910	0,1950
Min Abs Error	1,1E-05	8,2E-05	0,0006	0,0006	0,0002	2,7E-05	0,0002
Max Abs Error	1,0388	0,9980	0,9961	0,9779	0,9352	1,0341	0,9818
r	0,512	0,7116	0,5397	0,477	0,4998	0,4709	0,5119
Percent Correct	45,081	64,1791	57,5	60,5633	72	45,1612	63,7681

BEYOND VISUAL DATA

BEYOND VISUAL DATA: Compositional Data







Mechanical properties of archaeological materials

CONSTRAINTS

Practical Problem →

Task Constraints
(Level of Acceptability)
- Task Mechanics
  - Precision
  - Force
  - Nature of Action
- Efficiency
- Quantity
- Time Available
- Failure Consequences (Risk)

Locational Constraints
(Necessary or suitable locations or environments)

Material Constraints
- Available Materials, Sizes, and Costs
- Relative Performance
- Relative Wear/Failure Rates
- Ease of Working

Technological Constraints
- Available Technology
- Production Costs
- Repair/Resharpening/Replacement Costs
- Skill Required

Socioeconomic Constraints
- Mobility
- Transport Capacity
- Available Labor
- Storage/inventory capability

Ideological Constraints

→

Design Considerations
- Size and Weight
- Edge Angle and Form
- Prehension and Hafting
- Length of Use (Use-life)
- Degree of Specialed Use
- Reliability
  (robustness and "overdesign")
- Ease of repair/resharpening requirements
- Multifunctionality (versatility)

→

Production/Reduction & Resharpening Strategies

e.g.
- Expedient Block Core
- Biface
- Long-Lived Flake/Blade Tools
- Scavenging/Recycling
- Bipolar
- Groundstone
- Resharpening:
  - hard hammer (notching, continuous retouching, burinating, etc.)
  - billet
  - pressure
  - grinding

A schematic representation of the design and production process for practical lithic technology. This is a stepwise, sequential design process that results in the production of a tool. Once it is completed and the tool is tried out, it may lead to evaluation of the acceptability of results and reassessment of various factors, leading to a new round of tool production.

FUNCTIONAL ANALYSIS.

DIRECTLY INTERACTING WITH REAL OBJECTS

MEASURING MECHANICAL PROPERTIES

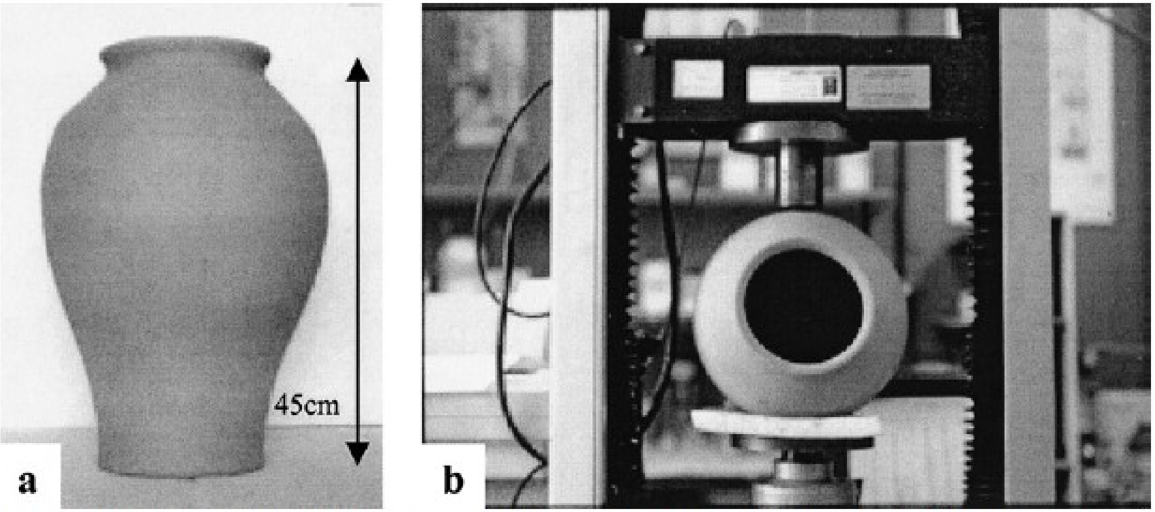
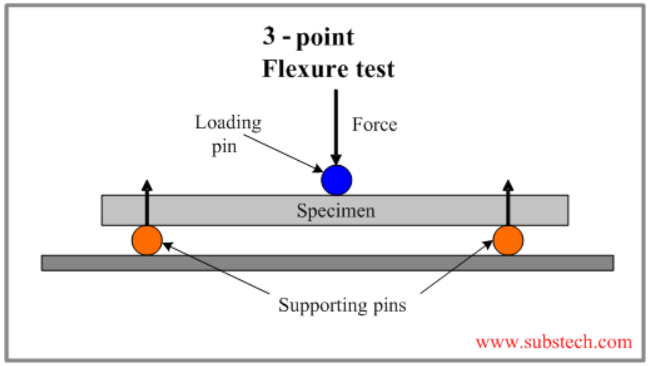


Figure 1. (a) The model jar manufactured for the purposes of developing and testing the FEA method. (b) Testing configuration of the test jar.



MEASURING PHYSICAL PROPERTIES

Physical properties - are those whose particular values can be determined without changing the identity of the substance: DENSITY, MOISTURE CONTENT, PERMEABILITY, SHRINKAGE

Friction properties – include the coefficients of *static*, *kinetic*, *and rolling* friction,

Thermal properties – *thermal conductivity, thermal diffusivity, thermal expansion coefficient, thermal shock resistance, specific heat, melting point, creep resistance*.

MEASURING MECHANICAL PROPERTIES

Mechanical properties – ThE value may vary as a result of the physical properties inherent to each material, describing how it will react to physical forces. The main characteristics are ELASTIC, STRENGTH and VIBRATION.

ELASTIC PROPERTIES:

modulus of elasticity, is the ratio of linear stress to linear strain.
Poisson's ratio is the ratio of lateral strain to axial strain.
Yield strength refers to the point on the stress-strain curve beyond which the solid starts to deform plastically and cannot be reversed upon removal of the Loading

MEASURING MECHANICAL PROPERTIES

STRENGTH PROPERTIES: The material’s mechanical strength properties refer to the ability to withstand an applied stress without failure, by measuring the extent of a material's elastic range, or elastic and plastic ranges together. Loading, which refers to the applied force to an object, can be by:

Tension –It can be quantified as *ultimate tensile strength*, which is the maximum amount of tensile stress a material can withstand while being stretched or pulled before failure. *Ductility* measures how much a material deforms under tensile load before breaking. It can be measured in percentage of elongation of a tensile sample after breaking. On the contrary, *brittleness* is the ability of a material to fracture with very little or no previous detectable deformation.

MEASURING MECHANICAL PROPERTIES

Compression – involves pressing the material together. In fact, it is the opposite of tensile loading. <u>*Compressive strength*</u>: is the maximum amount of *compressive stress* a material can withstand while being compressed before failure.
Hardness :A measure for material hardness can also be the *degree of abrasion*, which is the resistance to grinding force.
Bending – involves applying a load that causes a material to curve, resulting in compressing the material on one side and stretching it on the other. It can be quantified as *bending strength* and *flexural strength*.

FUNCTIONAL ANALYSIS.

DIRECTLY INTERACTING WITH REAL OBJECTS

MEASURING MECHANICAL PROPERTIES

Shear – involves applying a load parallel to a plane, causing the material on one of the sides of the plane to want to slide across the material on the other side. It can be quantified as *Shear strength*, which is the maximum amount of shear stress a material can withstand before failure. *Shear strain:* change in the angle between two perpendicular lines in a plane. *Shear modulus* (or modulus of rigidity, ratio of shear stress to shear strain, measures the stiffness of materials indicating the resistance to deflection of a member caused by shear stresses.

Torsion – Torsion strength indicates the applied force which causes twisting in a material.

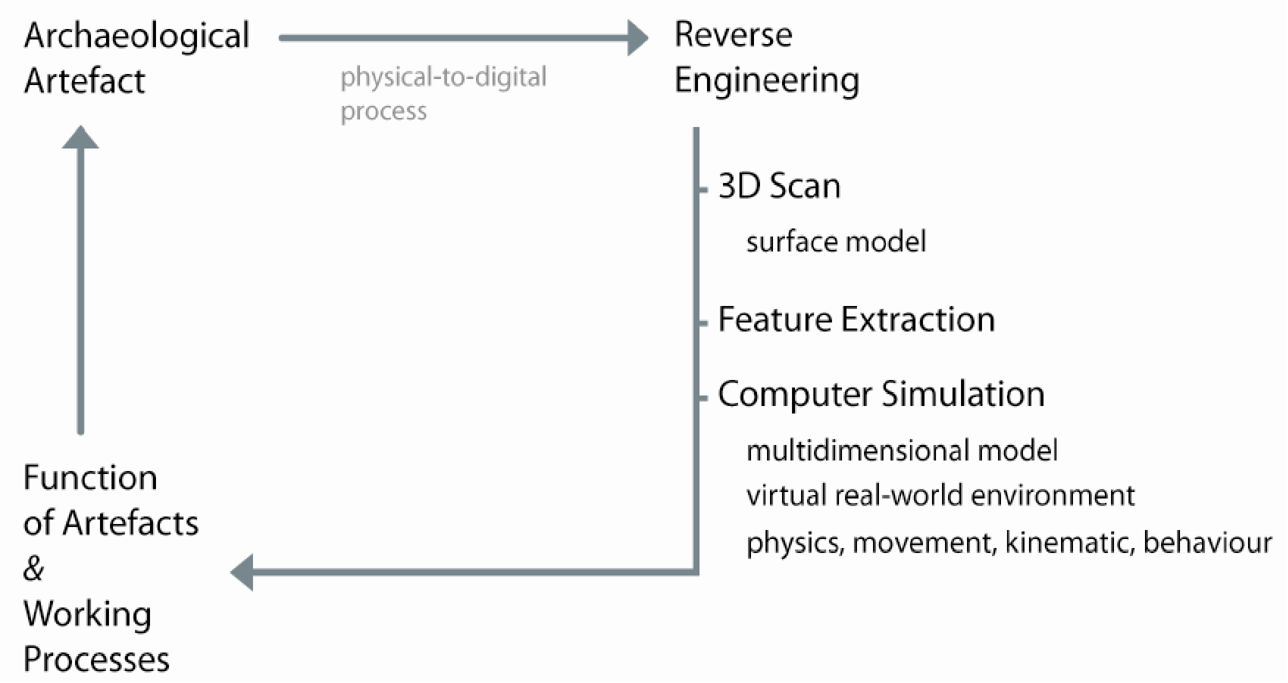
Fatigue – *Fatigue limit* refers to the maximum stress a material can withstand under cyclic loading. This resistance to failure under particular combinations of repeated loading conditions is measured.

FUNCTIONAL ANALYSIS.

DIRECTLY INTERACTING WITH REAL OBJECTS

Imagine the answer of a Museum director when we ask her to break a prehistoric object in order to measure its structural and mechanical properties. Given that prehistoric and ancient objects tools not always can be used in the present nor “touched” to preserve its integrality, we are limited to the possibily of manipulating a virtual surrogate of the object.

REVERSE ENGINEERING

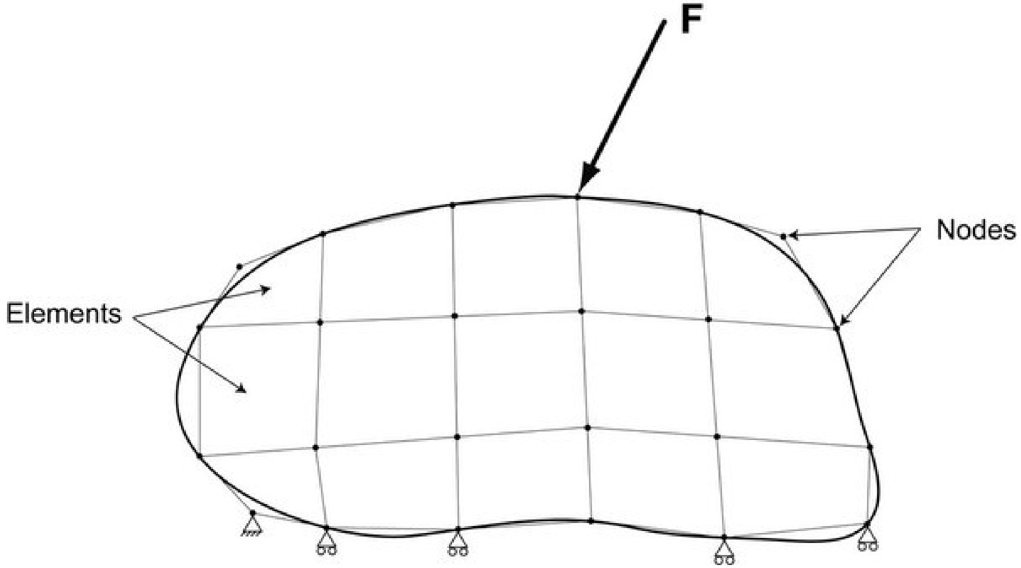


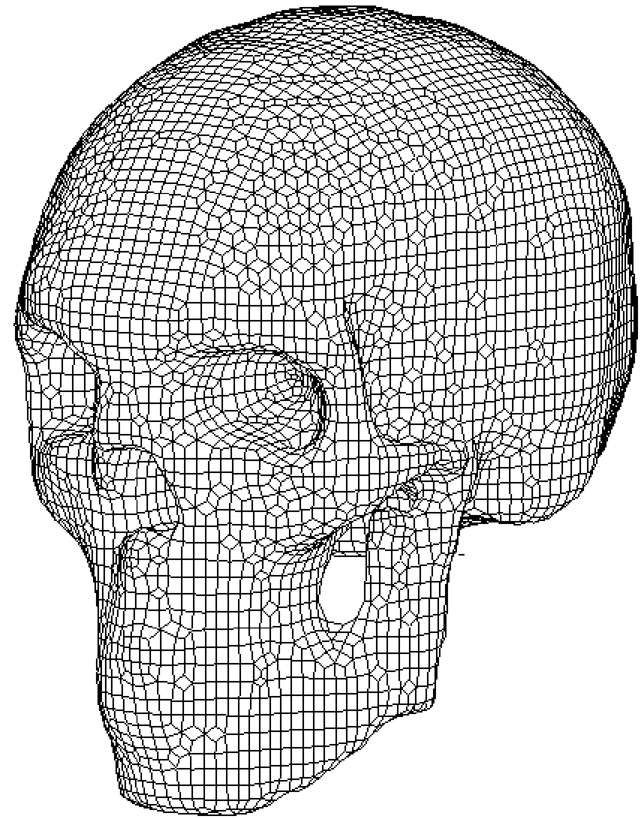
Reverse Engineering is the process of extracting missing knowledge from anything man-made, by going backwards through its development cycle and analyzing its structure, function and operation. It consists of a series of iterative steps, each addressing different questions regarding, in this case, an overall artefact. These steps may be repeated as often as needed until all steps are sufficiently satisfied.

FUNCTIONAL ANALYSIS.

DIRECTLY INTERACTING WITH SURROGATES OF REAL OBJECTS

SOLID MODEL

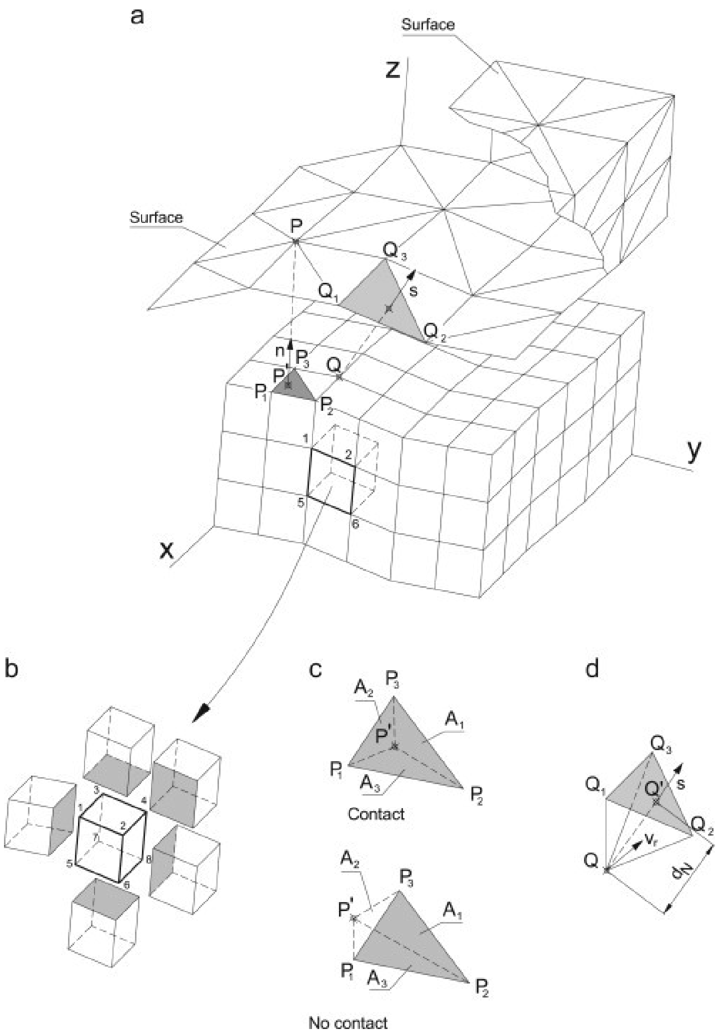


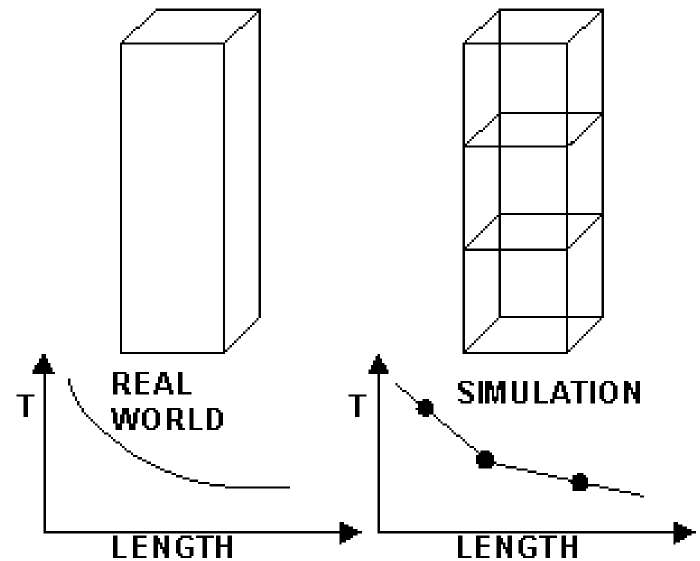


FUNCTIONAL ANALYSIS.

DIRECTLY INTERACTING WITH SURROGATES OF REAL OBJECTS

SOLID MODEL

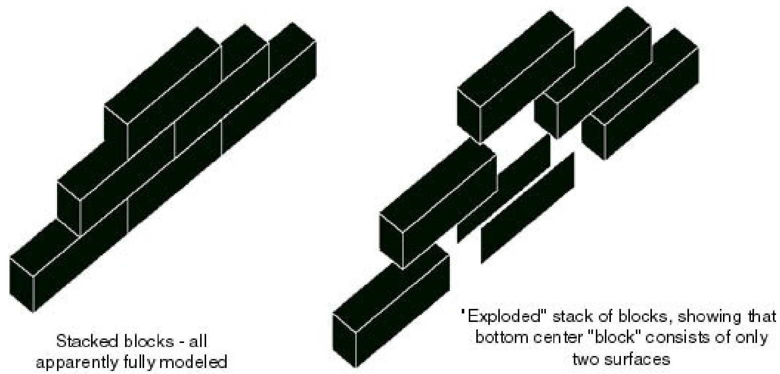


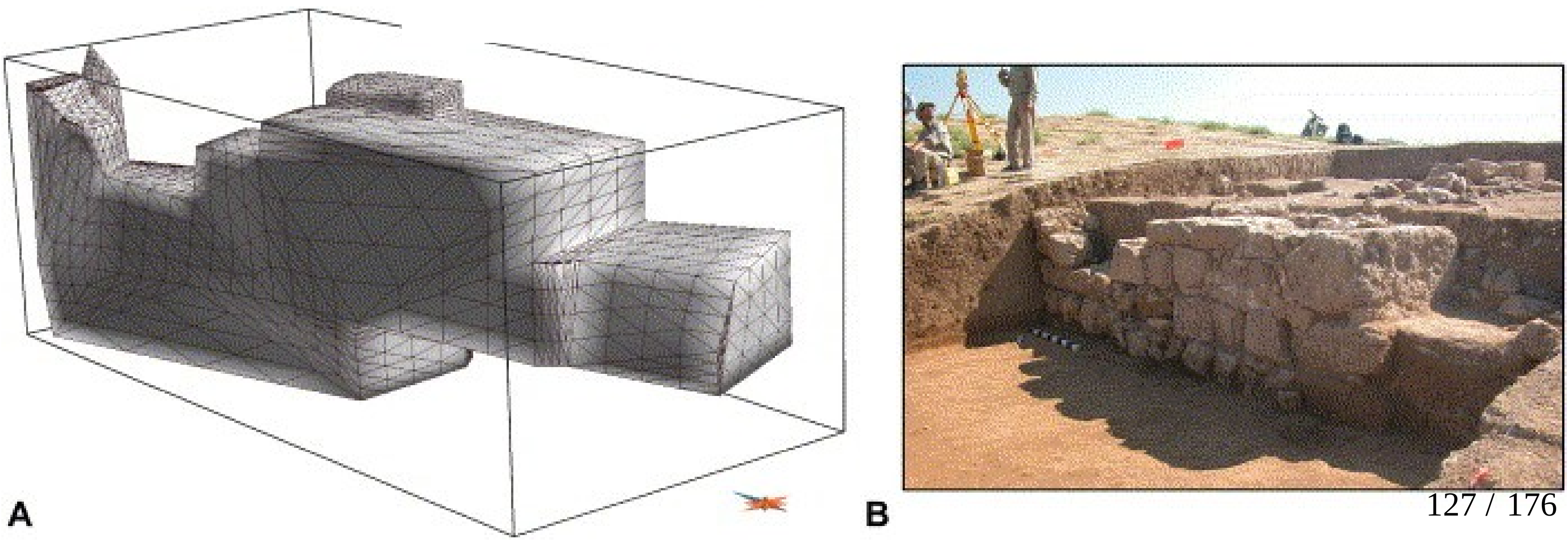


FUNCTIONAL ANALYSIS.

DIRECTLY INTERACTING WITH SURROGATES OF REAL OBJECTS

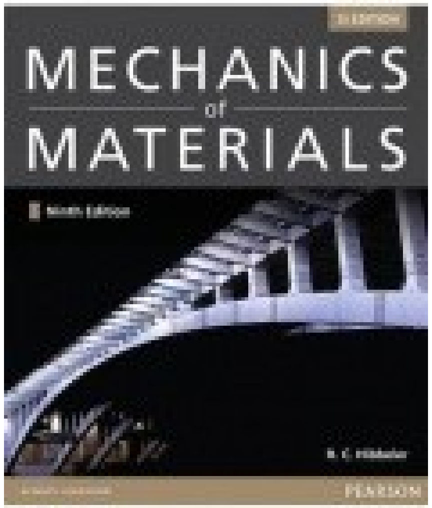
SOLID MODEL

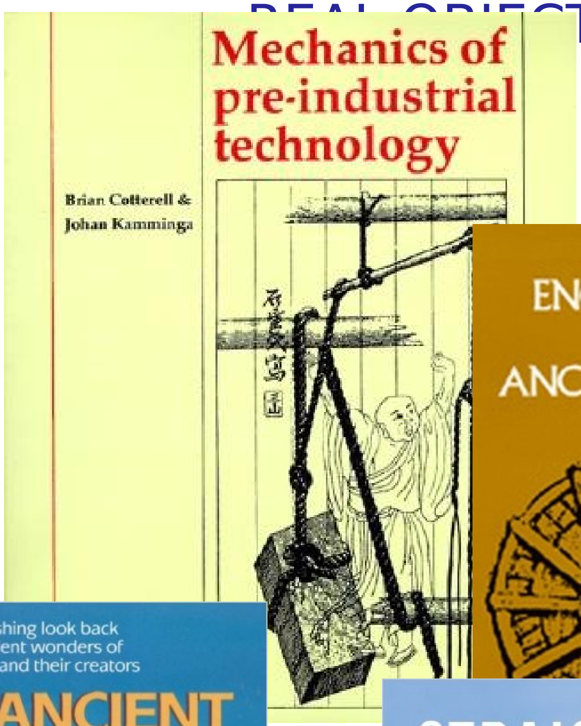


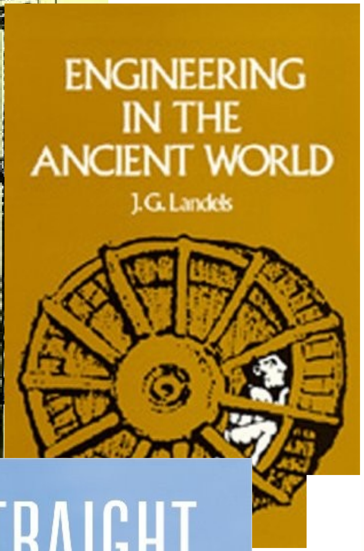


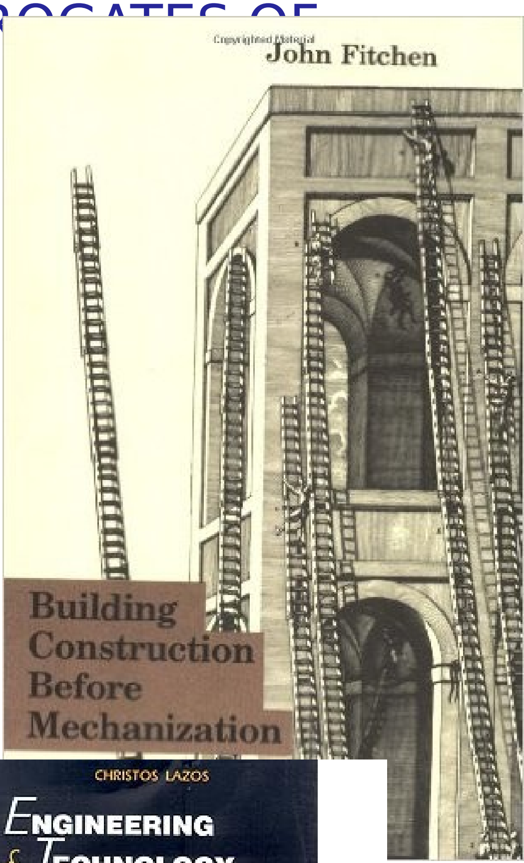
FUNCTIONAL ANALYSIS.

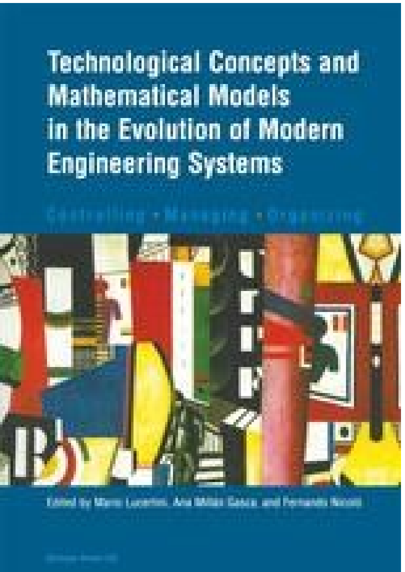
SIMULATING THE INTERACTION WITH SURROGATES OF REAL OBJECTS

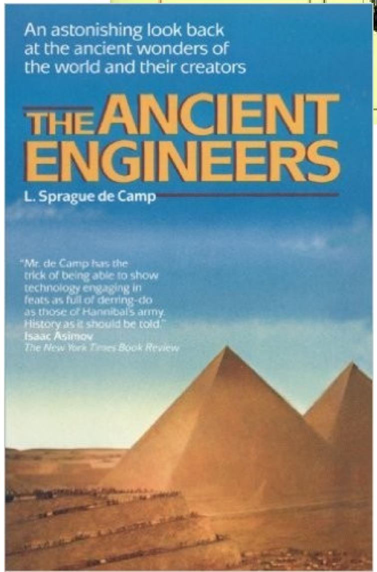


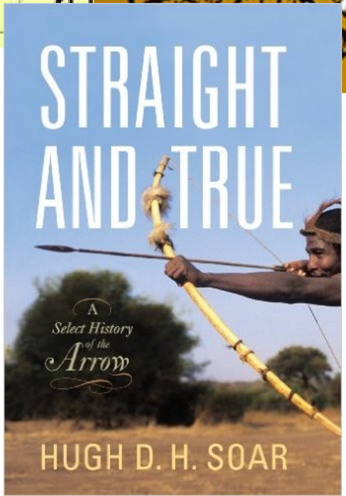


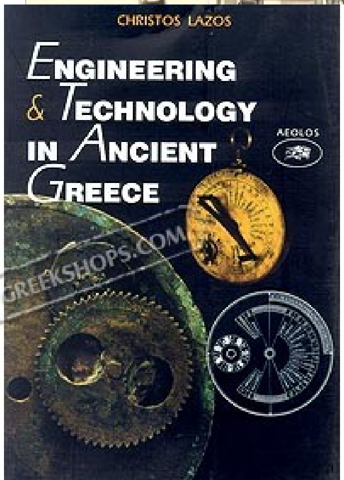






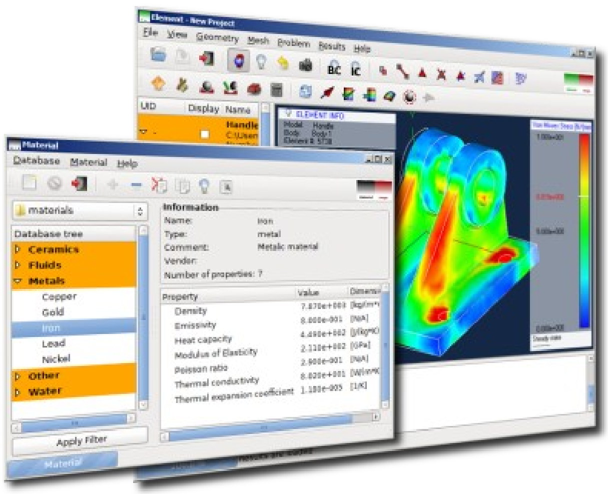


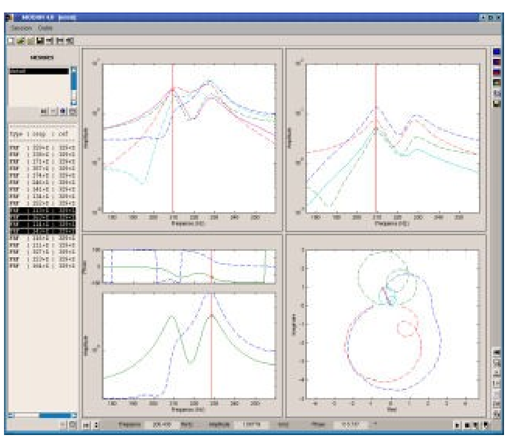




FUNCTIONAL ANALYSIS.

SIMULATING THE INTERACTION WITH SURROGATES OF REAL OBJECTS





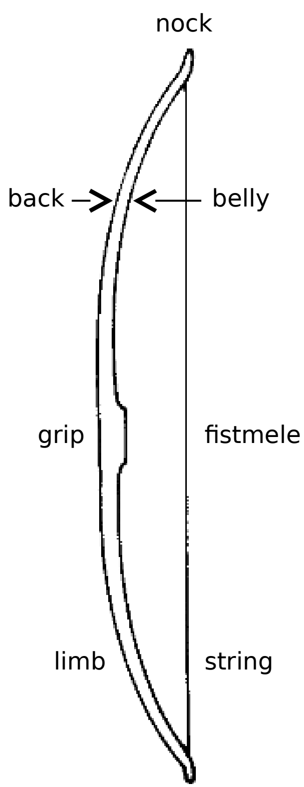
We can imagine different kinds of simulated interaction:

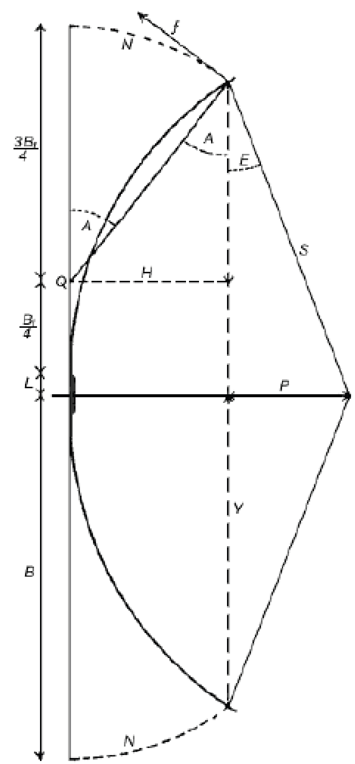
1) *static*, which calculates displacements, reaction forces, strains, stresses, and factor of safety distribution;
2) *frequency*, calculates stresses caused by resonance;
3) fatigue, calculates the total lifetime, damage, and load factors due to cyclic loading;
4) non-linear, calculates displacements, reaction forces, strains, and stresses at incrementally varying levels of loads and restraints;
5) dynamic, calculates the model's response due to loads that are applied suddenly or change with time or frequency

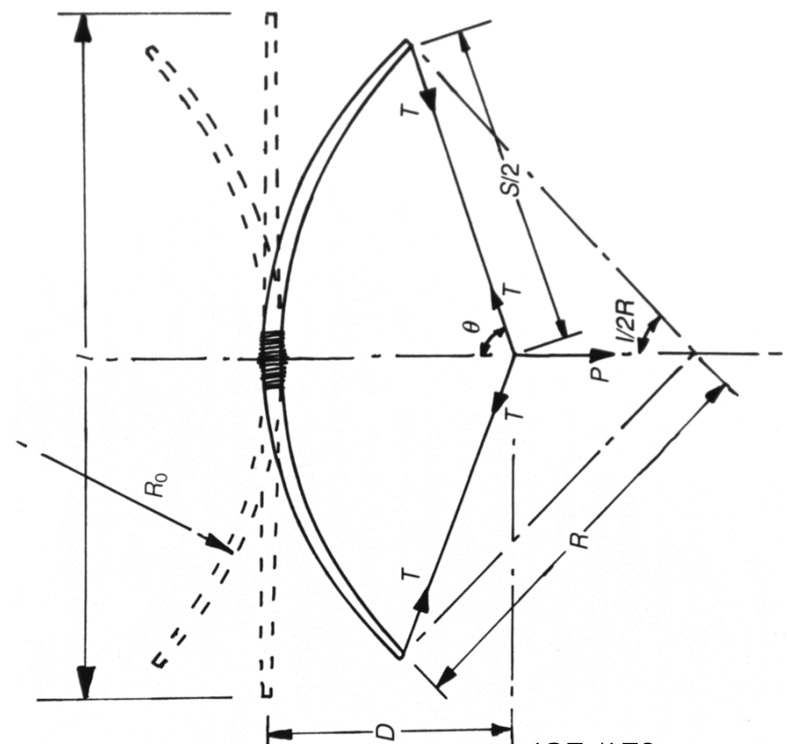
FUNCTIONAL ANALYSIS.

SIMULATING THE INTERACTION WITH SURROGATES OF REAL OBJECTS

J.A. BARCELÓ & V. MOITINHO 2011-2013: Prehistoric Bow and Arrow



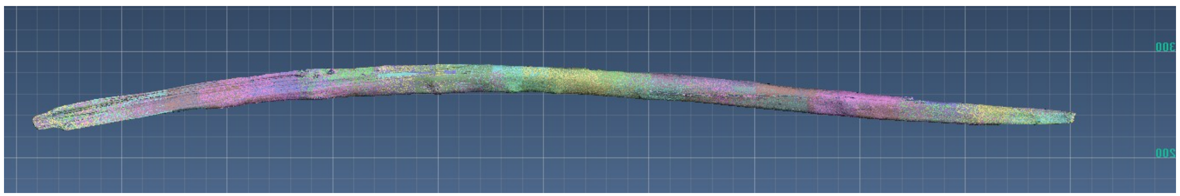




FUNCTIONAL ANALYSIS.

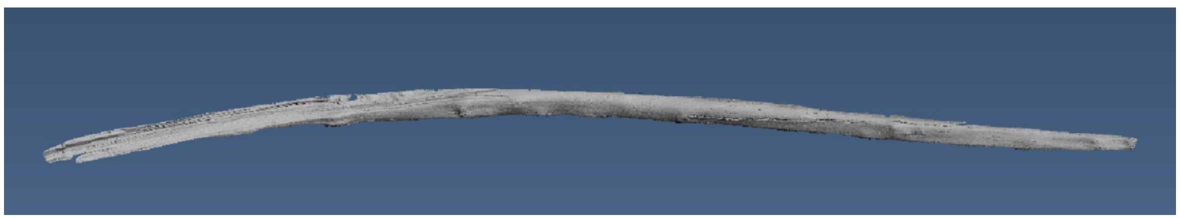
SIMULATING THE INTERACTION WITH SURROGATES OF REAL OBJECTS

La Draga (Banyoles). An early neolithic site

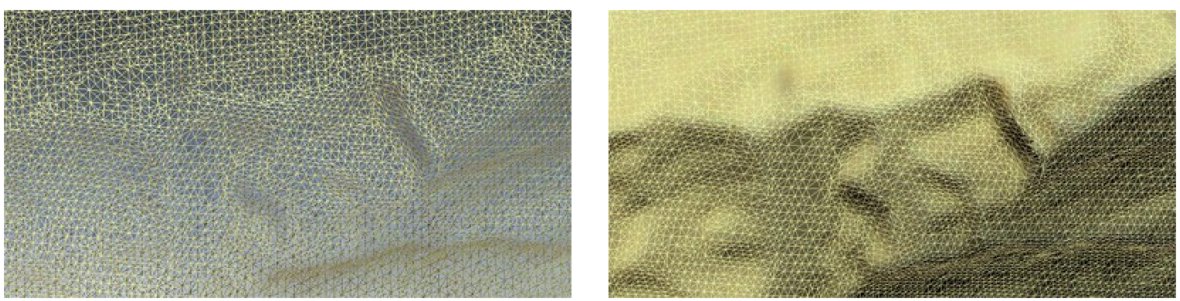


Bow (*D/02-JJ89-11*),
3D Scans alignment.

Total number of scans: 179, in 3 parts.
FOV: 90 mm, stereo.
Resolution 50 μm.



Bow (*D/02-JJ89-11*).
Merged polygonal mesh - 3D digital surface model.

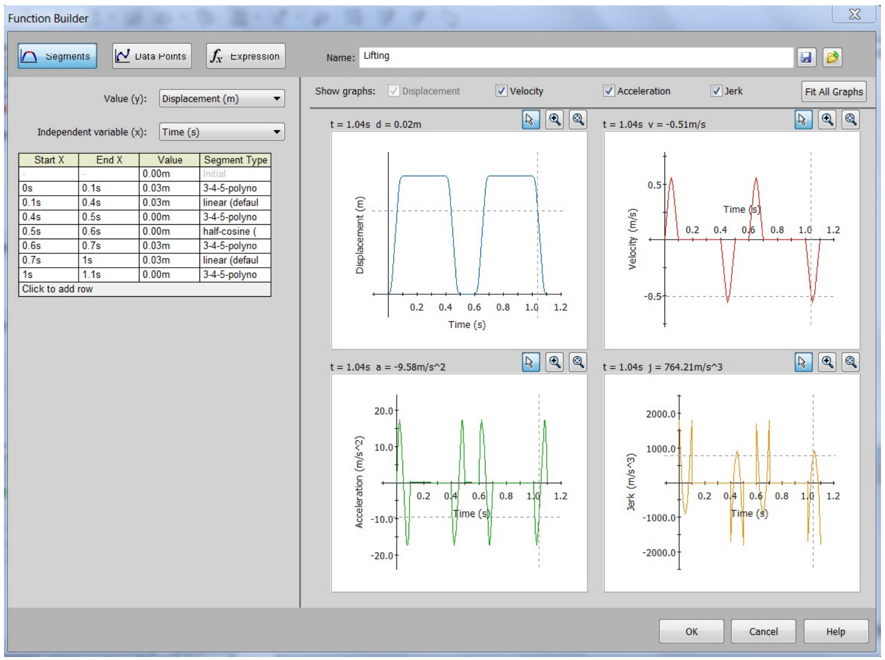


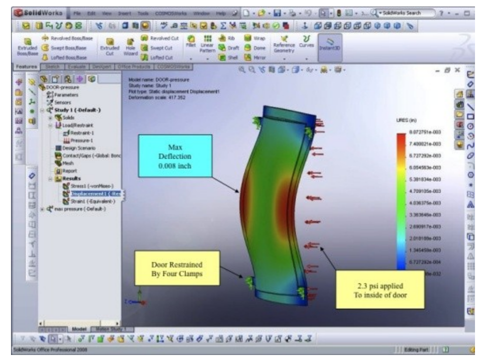
Polygonal mesh with poly-faces , detail.

FUNCTIONAL ANALYSIS.

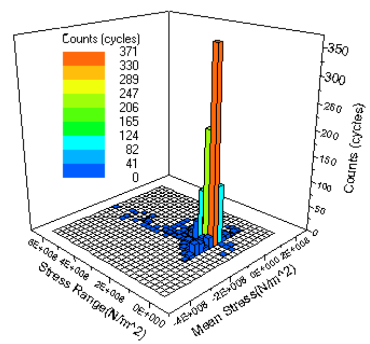
SIMULATING THE INTERACTION WITH SURROGATES OF REAL OBJECTS

J.A. BARCELÓ & V. MOITINHO 2011-2013: Prehistoric Bow and Arrow





Pressure, displacement and deformation analysis.

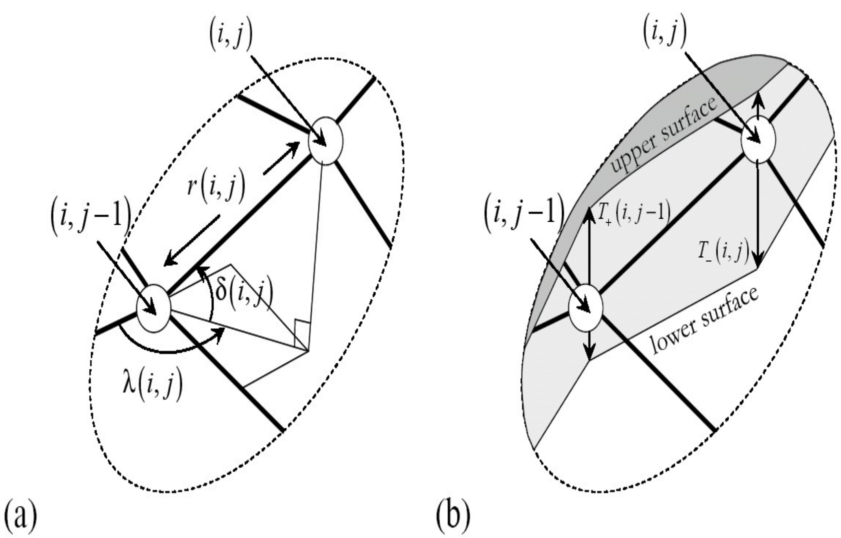


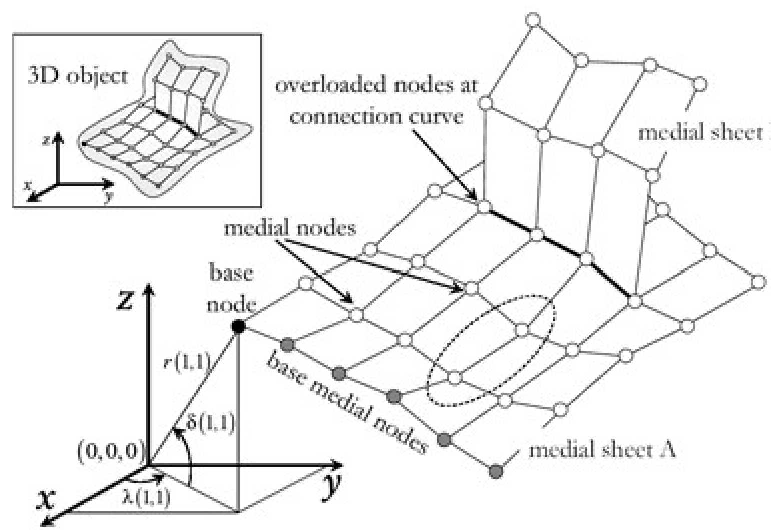
$[M]\{a\} + [C]\{v\} + [K]\{x\} = \{F\}$

Where:

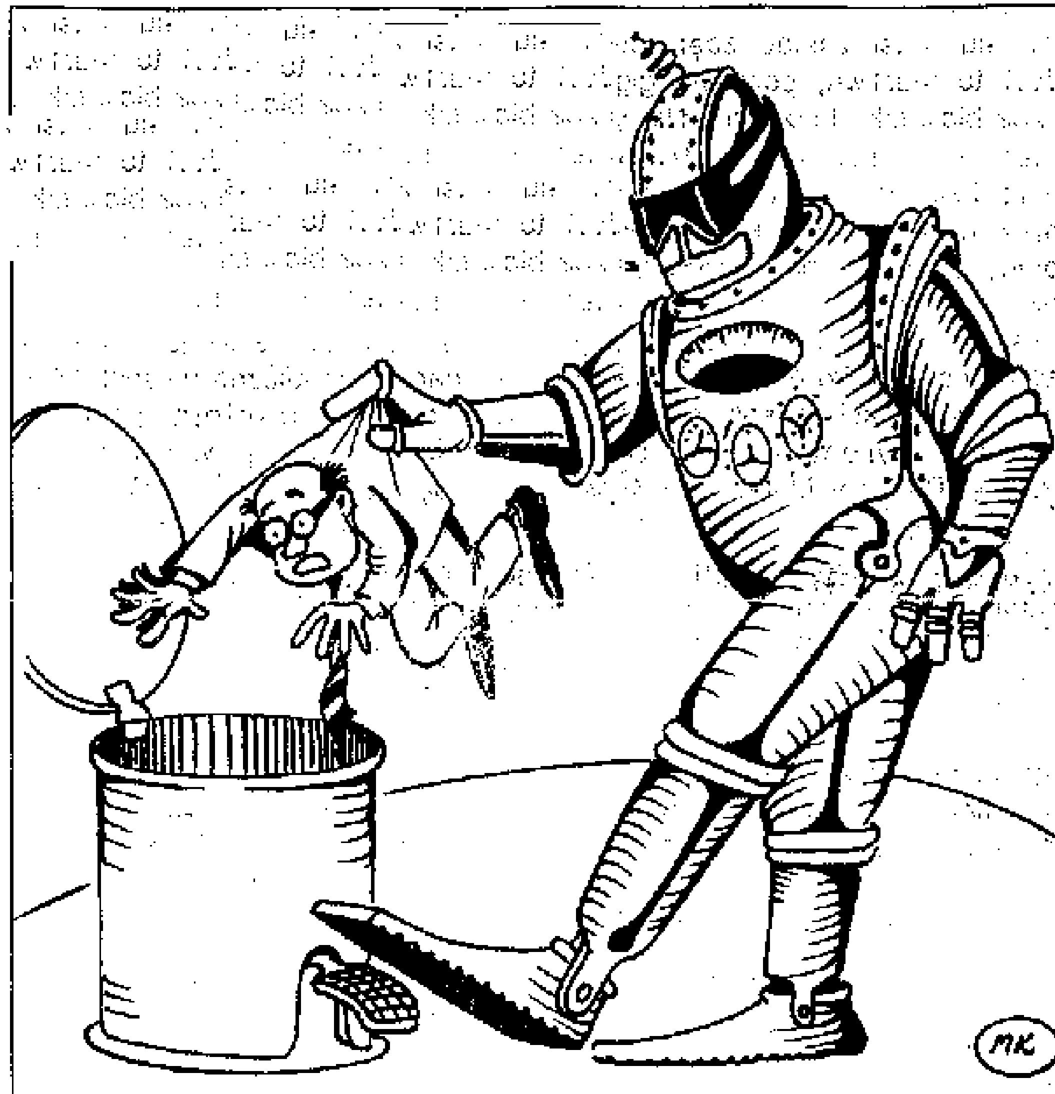
M = Mass matrix	a = acceleration vector
C = damping matrix	v = velocity vector
K = Stiffness matrix	x =displacement vector
F= external force vector	

Neolithic Axes



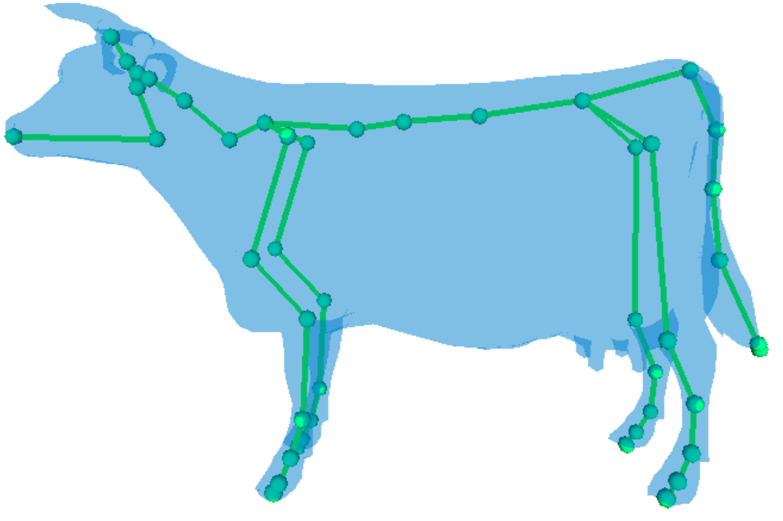


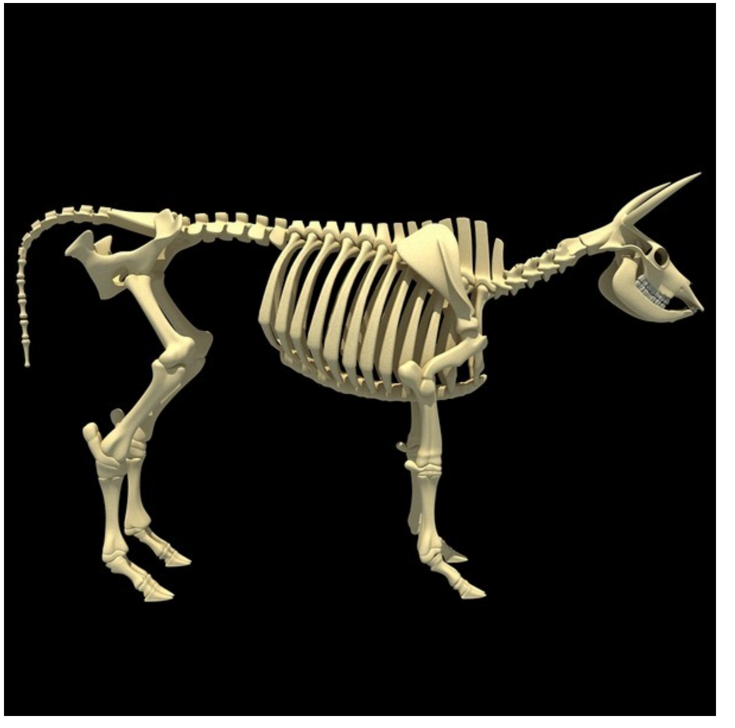
Computer Simulation



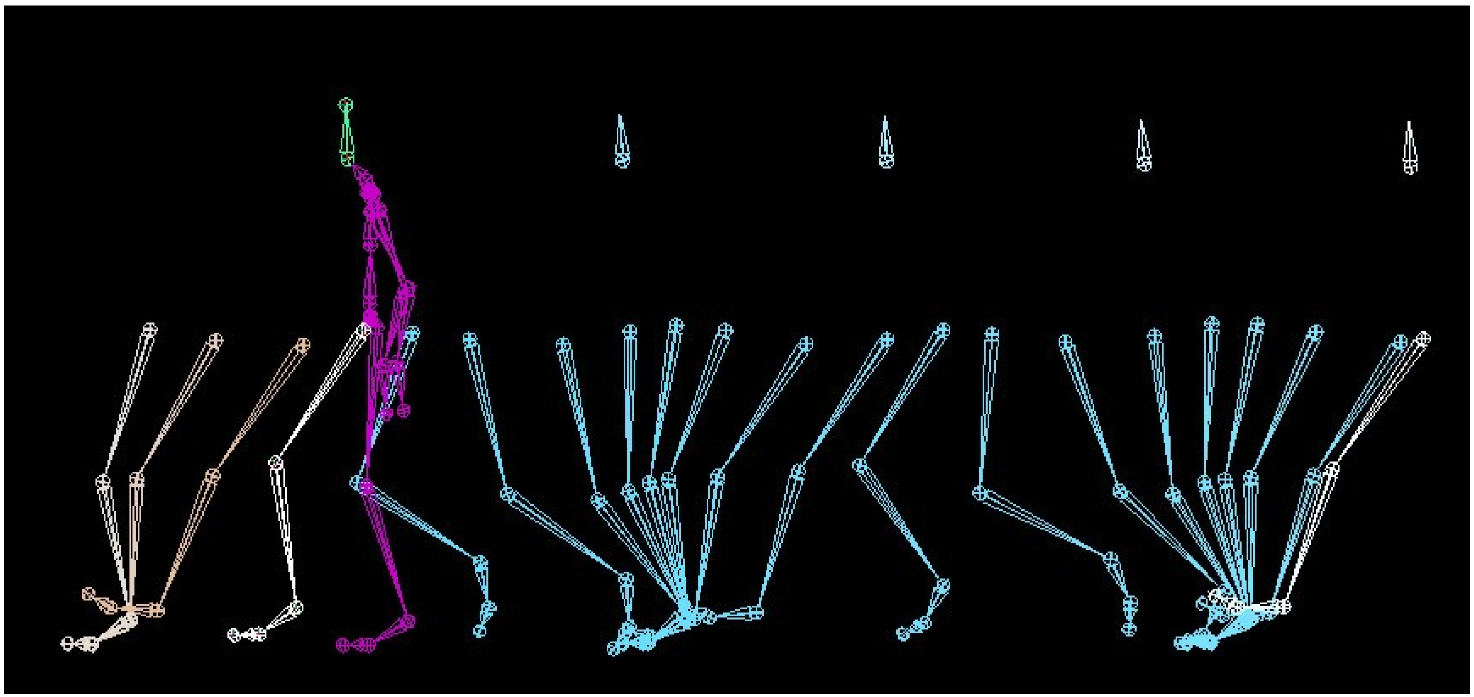
Rys. Marek Klukiewicz

NCIONAL DE RESTOS OSEOS. DEL ANIMAL SALVAJE
CION. Kaveh Youssef





NCIONAL DE RESTOS OSEOS. DEL ANIMAL SALVAJE CION



Laboratori d'Arqueologia Quantitativa + Laboratory for Socio Dynamics Simulation / UAB Universitat Autònoma de Barcelona

ONAL DE EDIFICACIONES PREHISTORICAS. PALAFI